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JOURNAL of the AMERICAN WELDING SOCIETY

VOLUME 13
NUMBER 3

MARCH
1934

Published Monthly

FOR THE ADVANCEMENT OF THE SCIENCE AND ART OF

WELDING

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Pick up the Oxweld Secator, the newest development in oxy-acetylene cutting machines, and put it to work wherever hand cutting is too slow and machine cutting with a stationary cutting machine is impracticable. It weighs only 43 pounds, yet at the touch of a button it cuts with such amazing precision that for many purposes no machining is required.

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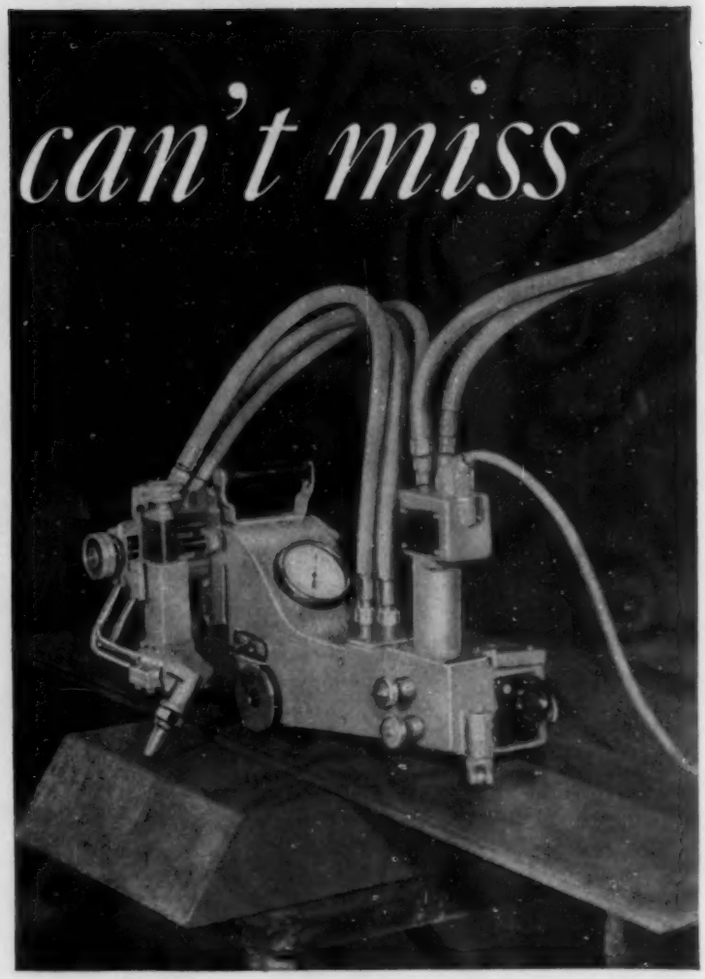

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Operates on 110 or 220 volt d.c. or a.c., 25 or 60 cycles . . . . Rheostat governs motor speed and a speedometer indicates cutting speed in inches per minute . . . . Electric switch starts the machine and turns on the cutting oxygen simultaneously . . . . Blowpipe can be adjusted 3 in. laterally and 4 in. vertically. It can be inclined laterally in either direction up to a maximum angle of 45 deg. for beveling . . . . Ventilator fan, mounted on motor shaft, cools all enclosed parts. Chassis protects working parts against dust, sparks, and molten metal.

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A new booklet describing the Oxweld Secator and three other new Oxweld Cutting Machines is now being printed. A request on your business letterhead addressed to the nearest Linde District Office will bring it to you as soon as it is off the press.

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WM. SPRARAGEN
Editor

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SOCIETY AND RELATED ACTIVITIES

Fall Meeting

The Fall Meeting of the AMERICAN WELDING SOCIETY will be held in New York during the week of October 1st in connection with the National Metal Congress. The Meetings and Papers Committee is making every endeavor to make the technical sessions the most important ever held in the history of the Society. To this end it desires the cooperation of all the members in making known their wishes as to the kind of meetings and papers that they would like to have presented. Suggestions should be sent to W. Spraragen, Secretary, Meetings and Papers Committee, AMERICAN WELDING SOCIETY, 33 West 39th Street, New York, N. Y., on or before April 15th. Members who desire to prepare such papers are cordially invited to send in the titles of the proposed papers so that they may be considered by the Meetings and Papers Committee.

New Members—February 1934

Class "A"

Philip H. Weinberg—Philadelphia Electric Company, 1000 Chestnut St., Phila., Pa.

Class "C"

Harry D. Baker—Dennison Mfg. Co., Framingham, Mass.

B. M. Brown—Southern Pacific Lines, Houston, Texas. Proposed by A. E. Gaynor.

C. H. Burgston—Deere & Co., Moline, Ill.

J. W. Burnett—Union Pacific System, Omaha, Nebraska.

John Craig, II—Craig Shipbuilding Co., Long Beach, Calif.

Charles A. Day—Elliott Electric Co., 2186 W. 25th St., Cleveland, Ohio. Proposed by A. E. Gibson.

Fred J. Esslinger—Champion Rivet Co., Cleveland, Ohio. Proposed by A. E. Gibson.

J. S. Kollar—Todd Shipbuilding Co., Foot of Texas St., Mobile, Ala.

T. J. Lawless—Champion Rivet Co., Cleveland, Ohio. Proposed by A. E. Gibson.

W. R. McDonough—W. R. McDonough Co., National Bldg., Cleveland, Ohio. Proposed by A. E. Gibson.

G. Mianulli—4718-11th Ave., Brooklyn, N. Y.

C. H. Michel—Maryland Metal Co., Baltimore, Md.

M. F. Neeson—Alabama Power Co., Birmingham, Ala.

H. Newcom—Continental Steel Corp., Kokomo, Ind.

H. W. Pierce—New York Shipbldg. Corp., Camden, N. J.

A. L. Polson, Australian Iron & Steel, Ltd., Sydney, Australia.

John I. Quinn—U. S. Bureau of Public Road, Omaha, Nebraska.

John M. Rezepko—American Airways Inc., Cleveland, Ohio. Proposed by E. T. Scott.

John E. Steinman—The American Ship Building Co., Foot of 54th St., N. W., Cleveland, Ohio.

V. E. Tobin—Armco International Corp., Buenos Aires, Argentina. Proposed by A. F. Davis.

L. A. Wallace—Atlantic Steel Co., Atlanta, Georgia.

J. H. White—Florida Power & Light Co., Miami, Florida.

Frank A. Wilch—Harnischfeger Sales Corp., Representative, 525 Empire Bldg., Cleveland, Ohio. Proposed by E. T. Scott.

Gordon T. Williams—The Cleveland Tractor Co., Cleveland, Ohio. Proposed by E. T. Scott.

Class "D"

David Cullen—Hilyard Newbold Co., Norristown, Pa.

John Stasz—2319 Casmere St., Hamtramck, Mich.

Dan White—International Harvester Co., Chicago, Ill.

Machine Gas Cutting

The Air Reduction Sales Company has just issued an attractive book, entitled "Machine Gas Cutting." Here is the foreword: "A lance of light . . . a controlled blade of incandescence, cleaving solid metal in a clean, narrow cut, with a speed and ease almost magical . . . a process of forming parts with steel and iron . . . so simple, so flexible, so economical, that it antiquates certain traditional production methods, revolutionizes shop practice, and opens wide the door to better products and bigger profits . . . that is Machine Gas Cutting."

Typical illustrations of machine gas cutting, as well as a wide variety of automatic equipment developed to meet small and large shop requirements, are described and illustrated in this 92-page book.

As a matter of fact, it is one of the most attractive booklets from an artistic viewpoint. The large illustrations with silhouetted details focus attention on specific subjects. The first section is devoted to a demonstration of the advantages of machine gas cutting in a plant which has used multi-torch and other machines for a number of years. Information as to the quality of the cut, range of steels, cutting speeds, cost and other details are given. Other sections are devoted to pictorial representation of the wide variety of production cutting, including small, large, simple and intricate parts. The various types of machines are copiously illustrated by large page-bled pictures.

Robert Blair Fellowship

Among the list of new members of the Society is the name of D. Bruce Johnston, of London, England, a young British engineer who graduated from London University in 1929. Mr. Johnston has been granted one of two Robert Blair Fellowships awarded annually by the London County Council for the purpose of advanced technical study abroad and is spending about a year in this country studying American methods of electric welding, especially in its application to structural steel work. He expects to be here till about October and we wish to take this opportunity to assure him that all those connected with welding, and especially the members of this Society, will do all in their power to help him in so far as present conditions will allow.

Members desiring to communicate with Mr. Johnston may do so through the office of the Society.

XI. International Congress of the Acetylene, Oxyacetylene Welding and Allied Industries

The Eleventh International Acetylene Congress will be held in Rome this year from the 5th to 10th of June, and judging from the increasing interest shown in the use of acetylene, particularly in the improved methods of welding and cutting, there will be an important gathering of interested people from all parts of the world.

The number and quality of the papers to be presented by eminent scientists, and the discussions which will ensue, constitute a great attraction, which is enhanced by the thought of Rome in early June.

A Program of Proceedings and further particulars may be had on application to: The General Secretariat, XI. International Congress of Acetylene, 87 Via San. Claudio, Rome, Italy.

Revised By-Laws Adopted December 24, 1933

Article IV Section 6.—Nominations and Elections of the Officers shall proceed as follows:

(*a*) The Secretary shall mail on or before the first Tuesday in February of each year to each member entitled to vote a notice that Nominations for Officers must reach the Secretary not later than the first day of March. This notice shall outline the vacancies in elective officers that shall be filled at the next regular election and request nominations for such offices. This notice shall contain a copy of this section and the list of nominees recommended by the Nominating Committee and information that no name shall appear on the final voting ballot unless proposed by at least 25 qualified members. The notice shall also contain the names of the members of the Nominating Committee.

(*b*) The nomination blank must be placed in a plain envelope and sealed, then inserted in a second envelope and sealed. The voter will then write his name thereon in ink and mail it to the

(Continued on page 33)

SECTION ACTIVITIES

BOSTON

On Friday, March 16th, the Boston Section will visit the Austin-Hastings plant at 226 Binney Street, Cambridge. The program starts at 7:00 P.M., and will consist of:

Motion pictures showing machine tool operations.

Motion pictures showing resistance welding operations.

Demonstrations of metallizing.

Demonstration of the Raytheon welding machine.

Refreshments.

CHICAGO

The Chicago Section held its regular monthly meeting at the Bismarck Hotel on February 16th. The speakers were Mr. Hoyer, of Robert Gordon Company, Inc., who spoke on the "Welded Piping in the New Field Building," and the second speaker, Mr. Page, of the General Electric X-Ray Corporation, whose topic was "Industrial Uses of X-Ray."

This meeting was very well attended both at the dinner and at the meeting itself.

A special meeting was held at the Lightning Institute in the Chicago Civic Opera Building on February 20th at 8 P.M. The speakers were Mr. C. H. Jennings and Mr. W. W. Reddie of the Westinghouse Electric & Manufacturing Company. Their topics were "Welding Intake Gates for the Boulder Dam" and "Recent Developments in Welding Equipment and Supplies." This was also a very successful meeting and there was a record attendance of three hundred and fifteen people.

CLEVELAND

The regular monthly meeting of this Section was held at the Cleveland Engineering Society on February 14th. Mr. John C. Miller, Shop Superintendent of the Nickel Plate Railroad Company spoke on "Application of Gas Welding on the Nickel Plate Railroad." Mr. E. W. P. Smith, Consulting Engineer with the Lincoln Electric Company presented motion pictures of concentrated stresses, with the use of polarized light.

LOS ANGELES

The regular meeting of the Los Angeles Section was held at Cole's Cafeteria, Huntington Park, January 18th. Mr. George Raymond, Chief Engineer, Black, Sivalls & Bryson, spoke on "Welding for the Oil Industry." The talk was well illustrated with slides, showing part of the work in the oil industry which is being accomplished by means of welding. Mr. Raymond very ably gave a résumé of the progress of welding from its hit-and-miss beginning to present modern methods. Mr. Raymond also showed his motion pictures of "wild" oil wells in the mid-continent field.

The following officers were elected for the ensuing year:

Chairman—Frank A. Longo, Southern Pacific R. R.

Vice-Chairman—Frank L. Howard, Smith-Emery Company.

Secretary—Charles E. DeLong, Air Reduction Sales Co.

Executive Committee:

P. L. Sterkel, Western Pipe & Steel Company.

V. M. Goode, C.M.M., U. S. S. *Medusa*.

C. E. McGinnis, Board Mech. Engrs., City of Los Angeles.

J. C. Blake, Victor Welding Equipment Company.

B. M. Laulhere, Southern Calif. Gas Company.

NEW YORK

A joint meeting of the Metropolitan Sections of the American Society of Mechanical Engineers, American Society of Civil Engineers and the New York Section of the AMERICAN WELDING SOCIETY, will be held in the Auditorium of the Engineering Societies Building, 29 West 39th Street, on March 13th at 8:00 P.M. An elaborate presentation of the special features of this vast engineering project now under construction in the Boulder Canyon, including a detailed discussion of the stress problems encountered in the design of its penstocks. The program includes: Dr. Elwood Mead, presiding, Commissioner of Reclamation, Department of the Interior, Washington, D. C. "Special Features of the Boulder Dam Project, Including Penstocks," by J. E. Trainor, General Superintendent of the Babcock and Wilcox Company, and "Stresses and Strains Involved in the Boulder Dam Penstocks," by S. C. Hollister, Professor, Department of Civil Engineering, Purdue University.

PHILADELPHIA

At the February 26th meeting of the Philadelphia Section, Mr. J. G. Hartley, Assistant Engineer, Maintenance of Way Department, Pennsylvania Railroad Co., presented a paper on "Reconditioning Rail Ends."

Mr. S. C. Clark, of the Technical Publicity Department, Linde Air Products Company, will be the speaker at the March 19th meeting. His subject will be "Reclamation in the Automotive Field."

PITTSBURGH

A most interesting talk on the "Recent Developments in the Resistance Welding of Aluminum" was given by D. I. Bohn, Engineer, Aluminum Company of America, before the members of the Pittsburgh Section, February 21st in the Fort Pitt Hotel. Mr. Bohn illustrated his talk with slides showing specimens of welded aluminum, after which the meeting was thrown open for general discussion and examination of welded samples brought by Mr. Bohn. Considerable interest was manifested by those present and it was apparent that welding of aluminum is becoming a matter of great interest to all.

The next regular meeting of the Pittsburgh Section will be held in the Fort Pitt Hotel, March 21st, when a paper will be presented by the Hartford Steam Boiler Inspection and Insurance Company on "The Attitude of Insurance Companies toward Welded Pressure Vessels."

SAN FRANCISCO

The February meeting of this Section was held on the 16th. Lieutenant-Commander Ret. C. G. McCord of the Industrial Materials X-Ray and Radium Test Laboratories gave an interesting talk on "X-Ray Investigation of Welds and Other Metals" and actually showed the methods employed and the results obtained.

EMPLOYMENT SERVICE BULLETIN

SERVICES AVAILABLE

A-214. Executive and Sales Engineer desires position. Can submit references. Forty years of age. Graduated from Carnegie Institute of Technology and studied metallurgy in London. Have been connected with the Westinghouse Electric & Manufacturing Company as its Testing Engineer and Sales Engineer. Assistant to Vice-President for another Company; Commissioned Officer in Navy; Sales Engineer, Lincoln Electric Company; European Sales Manager on welding apparatus for two companies; District Sales Manager of English Company. 1926 to present—in business, which have recently sold.

A-215. Sales Engineer desires position. Have had two years' experience with Bastian Blessing Company; eight years with Imperial Brass Manufacturing Company and seven years with Oxweld Acetylene Company.

Fabricating Welded Pipe for Boulder Dam

By W. A. CATHER

✦Mr Cather is Manager of the Advertising Department of the Babcock & Wilcox Co.

Fig. 1

Fig. 1—Field Fabricating Plant and Office Building of The Babcock and Wilcox Company at Boulder Dam.

This plant is fully equipped to fabricate by fusion welding and to test by X-ray, 14,500 ft. of pipe, 8½ ft. to 30 ft. in diam., from steel plate ranging in thickness from $^{7}/_{8}$ in. to $2^{3}/_{4}$ in. Fabrication of the pipe at the site of the dam is necessary because the finished pipe sections are too large to be transported by railroads.

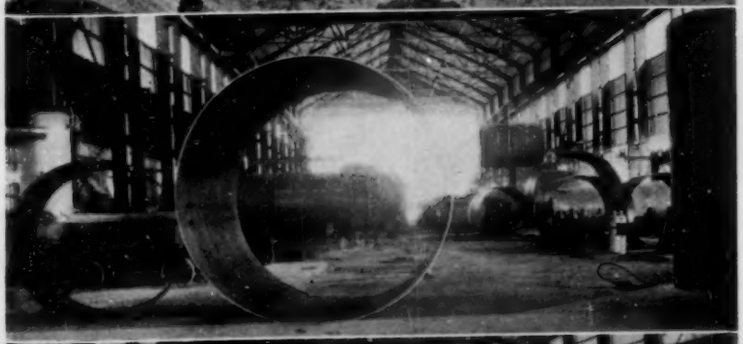

Fig. 2

The shop building is 520 ft. long by 90 ft. wide and is 56 ft. high from the floor to the bottom chord of the roof trusses. The total floor space, including that of a laboratory and foreman's office, contained in a lean-to on one side of the shop, is 51,500 sq. ft.

Fig. 2—Interior view of the Field Fabricating Plant.

Fig. 3

Assembled pipe sections, 8½ and 13 ft. in diam. can be seen in the foreground. The two cranes each have a capacity of 75 tons in the main hoist and 25 tons in the auxiliary hoist. Note the method of handling the sections in the shop by means of these cranes.

Fig. 3—The work in progress on the floor is the fabrication of steel pipes, 8½ ft. in diam., from plates $^{7}/_{8}$ and 1 in. in thickness. Other pipe having diameters of 13, 25 and 30 ft., will be made from plate ranging in thickness from 1 in. to $2^{3}/_{4}$ in. Approximately 400,000 lin. ft. of welding will be performed in the fabrication of these pipes.

Automatic welding machines are shown at the left. In the right foreground may be seen part of the indexing and drill-support mechanism for drilling girth seams in pipe sections 25 ft. and 30 ft. in diam.

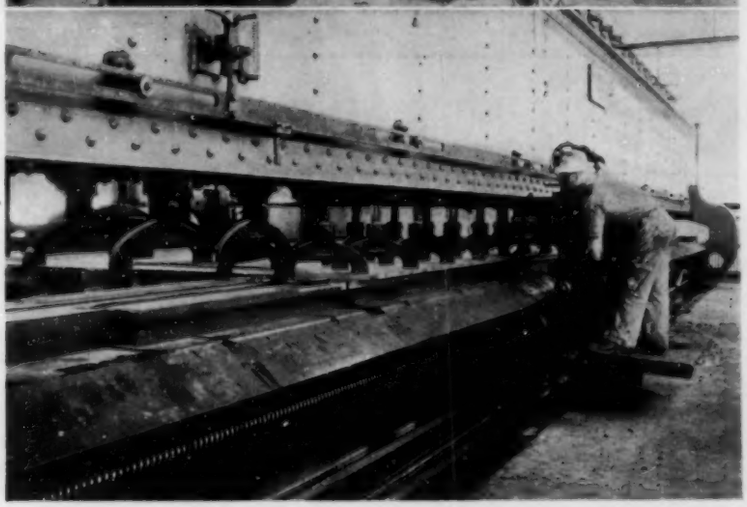

Fig. 4

Each of the cranes shown has a capacity of 75 tons in the main hoist and 25 tons in the auxiliary hoist. This crane capacity is necessary for the handling of erection sections of pipe 30 ft. in diam. and 24 ft. long, which will weigh about 150 tons. The span of the cranes is 85 ft., and the vertical lift is 50 ft.

Fig. 4—Operating side of the plate planer in the Field Fabricating Plant at Boulder Dam. The set-up of the plate and the tool holders is clearly shown in this photograph.

The edges of plates up to 2¾ in. in thickness will be planed and beveled by this planer preparatory to welding. The operator offers a ready comparison of the size of the planer

Fig. 5—The rolls of this machine are 3 ft. in diam. and 12 ft. high. A pipe section 8 ft. 6 in. in diam. is in process of rolling. Plates ranging in thickness from ⅜ to 2¾ in. will be rolled into pipe sections by this machine which, for its width, is heavier and more powerful than any other made to date.

Fig. 6—Welding a longitudinal seam on a 13 ft. diam. pipe section by an automatic fusion-welding machine.

Fig. 5

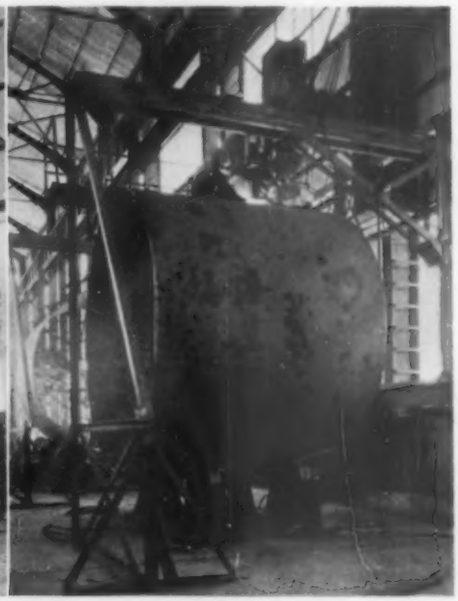

Fig. 6

Fig. 7—Portable X-ray machine for inspecting approximately 400,000 lin. ft. of welds. This method of taking X-ray pictures is unusual in that the machine is moved to the work instead of moving the work to the machine.

Fig. 8—X-ray photograph of a B. & W. weld. The location of the weld can be detected only by a slight difference in the shading of the print.

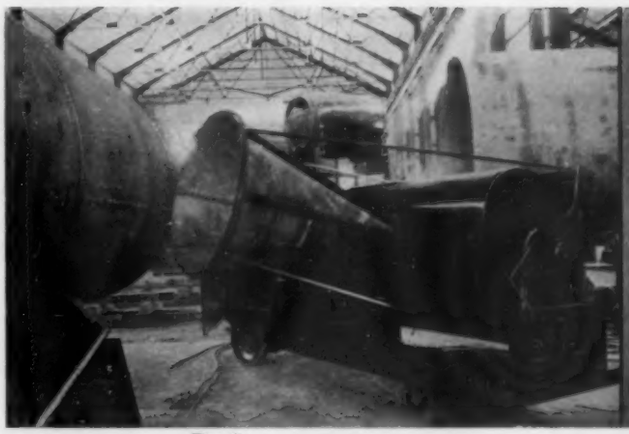

Fig. 7

Fig. 8

Fig. 9—Stress-relieving furnace at Boulder Dam. This furnace will be used to stress-relieve pipe sections as large as 30 ft. in diam. and 24 ft. long.

Fig. 10—Machining the end of an 8½-ft. pipe section. Set-up of internal spider shown. Large horizontal boring mill shown in the background.

Fig. 11.—Completed 13 ft. diam. sections, showing stiffener ring and support brackets assembled on pipe.

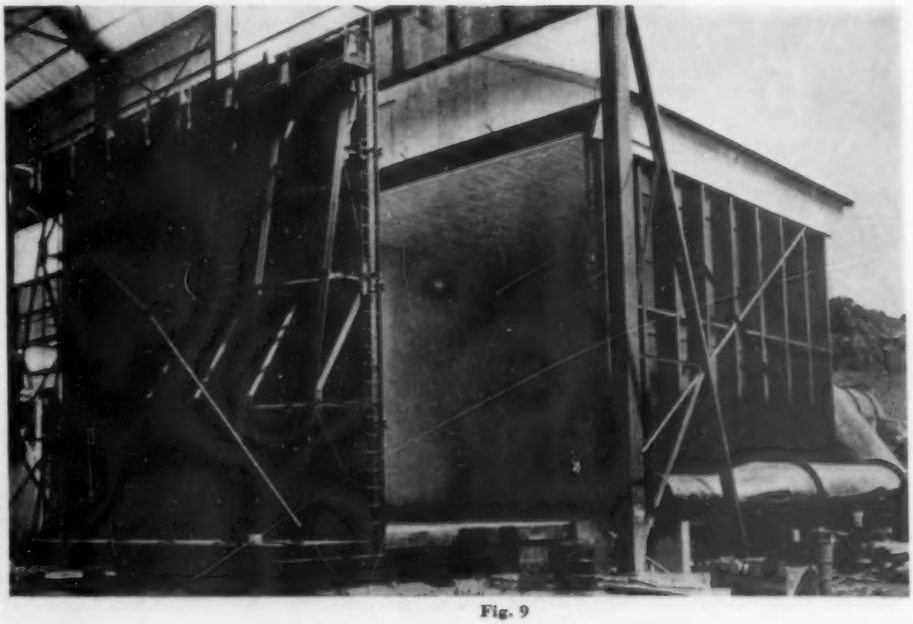

Fig. 9

Fig. 10

Fig. 11

Discussion of Paper on "Welding in a Large Shipyard"

By DAVID ARNOTT

✦Paper on "Welding in a Large Shipyard" was presented by Mr. G. H. Moore, Jr., Newport News Shipbuilding and Dry Dock Company, at the Fall Meeting, A. W. S., Detroit, Oct. 2 to 6, 1933, and was published in the November 1933 issue of the Journal of the A. W. S. Mr. Arnott is with the American Bureau of Shipping.

MR. MOORE in his valuable paper gives an interesting résumé of the welding processes in use by the Newport News Shipbuilding and Dry Dock Company, a shipyard which has done outstanding pioneer work in developing shipyard welding. It is not so many years ago since the use of welding in shipyard practice was confined to unimportant structural details, and the present satisfactory stage of development has only been reached as the result of continuous research and experimentation in welding technique carried out at Newport News and other large shipyards. Considerable prejudice had to be overcome, and this is not surprising, as the experience of owners, superintendents, etc., with some of the early welding repairs had been none too good.

The problems involved in the design of a structure such as a bridge or a building are comparatively simple as compared with those of a ship structure, which must necessarily be propelled through the water with an ever-varying distribution of the load and the support. Absolute reliability in service is an essential consideration to be kept in view in the design of a ship's hull and machinery, so that, as Mr. Moore very properly states, ship welding had necessarily to be developed on a conservative and sound basis. However, the progress made in the last ten years has been remarkable, and considerable credit for this advance is due to the encouragement given by the Navy Department, which is essentially interested in any new developments in ship construction which will tend to reduce weight without sacrifice of structural efficiency.

The American Bureau of Shipping has also done its part to encourage electric arc welding in merchant shipbuilding, and was the first classification society to eliminate the notation "Experimental" after the classification symbols of a welded ship. It is true that all welded ships so far classed with the Bureau have been comparatively small, not exceeding 230 ft. in length, and are mostly barges designed for harbor and short coastwise service where the major hull stresses are comparatively low, but this only goes to emphasize the fact that the development of ship welding has been along sound and conservative lines. There is no reason, however, why larger seagoing ships should not be completely welded, provided our shipyards are prepared to build such ships at prices not exceeding the costs of an all-riveted job. The use of heavy coated rods will be obligatory for welding important structural members, and the necessity for avoiding distortion and keeping residual stresses within reasonable limits is, of course, obvious. The present shipbuilding shapes, i.e., channels, bulb angles, etc., were designed for riveting, and special sections suitable for welded construction will have to be developed and made available by the steel manufacturers if we are to get the benefit of the maximum savings in weight in an all-welded job. Our shipyards were all laid out and equipped for riveted work, and obvious changes in this respect are necessary in order to derive the fullest economic advantages from ship welding.

Mr. Moore's paper is descriptive rather than controversial, and no objection can be taken to his conclusions. The examples given in the paper of some actual applications of welding carried out at the Newport News shipyard under his direction are extremely interesting and will serve to show to those of our members who are engaged in structural work other than shipbuilding that we shipbuilders are not behind the times so far as welding is concerned.

By **HARRY W. PIERCE**

†Mr. Pierce is connected with the New York Shipbuilding Company.

IT CAN readily be seen from this admirable review of the work in one of our largest yards that the welding problems encountered in ship work cover nearly every application of the art. It is only regretted that the scope of work is so large that a review in its entirety must touch necessarily upon only the high lights. As a member of an organization that has pioneered so greatly in the welding field, Mr. Moore can and, it is to be hoped, will present his views of particular phases of these applications at future meetings.

From the standpoint of welding, it is fortunate perhaps that the Disarmament Treaty set limits of displacement. There is no greater stimulus to a designer than a rule which limits this important factor and forces every possible effort to be made to get the most in offense and defense from a set weight of steel. Not all the reduction in weight of naval ships is due to welding, for weight limitation led to much refinement in all design, but the importance of welding toward weight reduction can hardly be exaggerated. It is true that this leads to expensive construction where weight saving becomes the all-important factor, but its benefit has been the development of management and production methods which have materially reduced the cost of more ordinary, simple construction.

Technical advance in welding outstripped development in management and production methods relating to its use. A ship itself is a complex thing; the organization that builds it, involving almost every trade and branch of industry, is no less so. Allied with the conservatism of men who realize the rigorous tests that sea service puts to a ship, was the difficulty in fitting into the organization a method of fabrication which bids fair to revolutionize every branch of shipbuilding. Shipyards engaged in naval work were literally forced to develop welding both in a technical and management sense to a degree which would have been thought impossible ten years ago. Although welding applications are far greater in naval than in merchant ships to date, the latter will profit by this development.

As Mr. Moore points out, the development of ductile weld metal was of the greatest importance in the structural part of ship work. The writer has listened to a number of debates over the importance of this property—to the shipbuilder who deals in highly indeterminate structures, in joints of peculiar size and frequently great length, it is paramount. The development of a covered rod for general position use, which permitted the welding of longitudinal members of the ship, made possible its application to complete hull fabrication.

One of the outstanding problems to which Mr. Moore refers is that of warping and shrinkage. While related, they are really separate problems, springing from the same cause, but differing in effect. Since welding involves the application of heat and the deposit of molten metal, shrinkage, usually accompanied by warping, is inevitable. In a ship the problem of warping is intensified by the predominance of flat or surfaces so slightly curved as to furnish no stiffness of form. The use of a great deal of continuous welding to obtain water-tightness increases the amount of shrinkage and, while individual welds may cause shrinkages measured in thousandths, the aggregate in a ship of ordinary size, if no allowance is made, would mean a serious variation from the designer's lines. Of greater importance is the failure to permit shrinkage which, if resisted, results in locked-up stresses. We have found it necessary to carefully lay out erection and welding procedures with this idea in mind, and then to adhere strictly to the program. In general, hull welding is started at a given point, and all attachments, seams and butts are made progressively from that point. The regulation and tacking or bolting of this welding is kept to the practical minimum, with slip lines of bolted or clamped connections when necessary to insure the highest degree of freedom in shrinkage to each part. By experiment and data from previous work, fairly close allowance can be made on individual plates and shapes in shop fabrication, so that the ship shrinkage is compensated for. In this regard, sub-assembly is of decided advantage wholly aside from possible improvement in facility of work with resultant economy. Large structures (bulkheads, foundations, decks) are welded on the ground and trimmed to size. Allowance need be made, therefore, for only the welding done in making up final connections.

If the completion of all parts of the hull could be carried along in the ideal manner, this problem would be considerably simplified. It is usually true, however, that many parts must be left loose for the eventual installation of machinery or large pieces of outfit. When it comes to closing in these spaces, each must be tackled as an individual problem. A simple case of this on a recent ship best illustrates the problem and emphasizes its importance. It was necessary to complete a considerable part of structure forward, extending from the keel upward several strakes of plating before the shell plate immediately aft of this point was erected. This latter plate, 30 ft. long and 5 ft. wide, was the transition point between the riveted and welded portions of the hull of this particular design. The forward end was made up by a welded butt joint, the after end a riveted lap. Seven lines of welding, five being frames intermittently welded and two bulkheads, continuously welded both sides, crossed the plate vertically or transverse to its long dimension. A welded longitudinal ran the whole length. The top and bottom seams of the plate were riveted joints.

From small-scale experiments, the shrinkage of the welded butt was expected to be about $^1/_8$ in. and the total shrinkage due to the beads attaching frames and longitudinal about $^3/_{32}$ in. more. Accordingly, the butt at forward end was regulated and tacked, the remainder of plate rather loosely bolted. Allowance on length plate made it possible to hold the after edge $^3/_{16}$ in. aft of position. All rivet holes were in plate, although safer practice would have dictated leaving the end blank. When the forward butt was welded measurements at after end showed that the plate had been pulled forward 0.110 in. The frames and longitudinal were successively pulled up, tacked and welded, working from the welded butt aft. The additional movement at after edge again agreed reasonably well with that predicted, the total movement being a scant $^3/_{16}$ in. The welding completed, all rivet holes were reamed to proper diameter and the lap and seams driven up.

Had the riveting been completed first, or even done after the butt was welded but prior to the frames, the result of the restriction to shrinkage can be imagined. An indeterminate and possibly high stress would have existed, which, coupled with only a moderate additional stress in a seaway, could result in failure of plate or weld. The order followed assured at least a minimum of residual stress.

Nothing in the foregoing procedure tended to eliminate or even reduce warping. In fact, the absence of tensile strains and the relative freedom of the plate to

shrink along the lines of weld (longitudinal weld shrinkage or "draw string effect") probably permitted a greater tendency to warp. Restraint by ribbands which permit slippage in plane of plate but resist bulging out of plane is effective in reducing warping, likewise careful control of welding to reduce heating. Corrective methods—shrinking the excess of metal in bulge by weld beads or the torch or peening the fame welds—are in general use, but correction is always expensive. However, if welding is given its full due for strength, the amount required will be so reduced that quite probably warping will be less serious; but as yet it remains a problem.

In the majority of cases warping is of little importance in the strength or utility of the surface. However, wrinkles in shell affect speed; uneven decks are highly undesirable walking surfaces, and it will be a long time before the seaman's eye will accept willingly any but a fair and pleasing surface. Obtaining such surfaces with a minimum of expense or correction, is a very real problem.

By C. S. MOODY

†C. S. Moody is connected with the Northwest Engineering Company.

THE writer was very glad to listen to the author's paper, most particularly because it showed a marked difference in welding procedure. By this the writer refers to the fact that at no time did the author mention the use of annealing after the welding operation. It would appear that there are two trains of thought, one advocating annealing, and the other not doing so.

In this particular, the writer wishes to point out that he has talked with several recognized authorities in the welding trade, and finds that they advocate the latter method. The greatest advocates of annealing would seem to be in the pressure vessel class. The writer would like to propose the following question for further consideration: Do we need annealing in ductile metal or does stress equalization by overstressing not give us a suitable answer, at least in many instances? This, of course, leads to the further question of stress equalization by service load applications (in ductile metals).

The writer has had the opportunity to see a large, complicated structure repeatedly overstressed in torsion. At the same time, stress readings indicated the removal of local stresses. This structure has now been in satisfactory service for over a year. Duplicate structures are in equally satisfactory service. These had no treatment after welding. There were also several others giving the same service that had been annealed.

I ask that we have further consideration by the Society of this economically important question.

The Development of Resistance Welding Electrical Power Control Devices

By RUFUS L. BRIGGS

†Article presented at Fall Meeting, A. W. S., Detroit, Oct. 2 to 6, 1933, by Rufus L. Briggs, Research Engineer, The Thomson-Gibb Electric Welding Company.

RESISTANCE welding, invented by Professor Elihu Thomson, is that division of the art of joining metals where the fusion heat is developed in the metals to be welded by passing a high density electric current through the desired joint at low voltage. The heat is generated by the electrical friction or resistance to the current flow and is directly proportional to the resistance of the metal and the square of the magnitude of the current.

Early experiments with this method of fusing metals were primarily interested in obtaining "a good weld" and it was a generally accepted truth that such a weld was obtained when the proper metal temperature and the proper mechanical pressure to produce fusion were developed in the process.

In studying the problem of obtaining the proper metal temperature it was found that four factors entered into the investigation. The type of metal or metals being welded, the magnitude of the welding current, the time period of application of the current and the heat dissipating conditions of the set-up, were the factors involved.

Several factors contributed to bring about changes in the devices used to control the electrical power delivered to the weld. With increasing demands on the welding capacity of the machines and the desire of the manufacturers for greater speed of production, a need was experienced for devices which would be more accurate in metering out power than was possible with manual methods. This led to the development of mechanical timing devices. It became necessary to pay more attention to the appearance of the finished weld. This still further increased the need for accurately metering out the welding energy. It was then necessary to develop electro-mechanical devices to "time" the welding period. With the appearance of the modern alloys, such as the stainless steel group, the maximum refinement of power controlling devices was necessary. As a result, pure electrical control devices were developed.

It is my intention to trace the development of these various control devices with respect to the resistance welding industry, explain their advantages and disadvantages and point out their proper fields of application.

Development of Electric Power Control Devices for Butt and Line or Seam Welders

To trace a history of the development of current magnitude control devices used in the resistance welding field is to trace the growth of butt and line welding. In this portion of the resistance welding field the necessity for careful metering of the period of application of the welding energy has only recently been an important problem. This new development will be discussed later. In all subsequent discussion by "timing problem" is meant the problem of measuring or metering out the period during which the welding current is applied to a given section, and by "magnitude control" is meant the

methods of adjustment of the magnitude of the welding current.

In butt as well as in line welding the timing problem is a factor which requires a certain amount of consideration. It is as necessary to turn the current off at the proper moment in butt welding as it is to have the proper push-up pressure. In line welding, too, the rate of speed at which the work travels between the welding rolls or the rolls travel across the work is a factor which must be considered. In butt welding, however, the time allotted to a weld is more or less fixed either by practice or production requirements, and the main problem is to adjust the current magnitude to the needed value in order to produce the weld. Similarly in line welding the relative rate of speed between the welding rolls and the work is not susceptible to varied adjustments over wide ranges. Welder manufacture practice has been to allow certain limited ranges of adjustment, but the customer is expected first to bring his current magnitude as close to the proper value as possible, and then use the roll speed adjustment to make minor changes in the welding heat if necessary.

The first welders were butt welders of small capacity used to join the ends of wire. The energy sources were a step-down transformer with a hand switch and a wire rheostat in series with the primary. The current was turned on and off manually, and the magnitude of the current was adjusted by the rheostat. Variable reactances of the inductive or capacitive type were subsequently designed to replace the wire rheostat. The variable inductive reactance was the more popular of the two, if not the best, due to its price advantage and was used in the industry for thirty years.

The first step forward in the development of control devices came with the appearance of the cut-out. This is a simple switch fastened on the butt welder which turns off the current when the proper amount of fusion has taken place. It was originally placed in series with the transformer primary. With the appearance of higher voltages supplied to the welding transformer another improvement in the control devices was made. The current to the welder was turned on and off by a separate magnetically controlled switch. The hand switch and the cut-out were now used to control the current operating the magnetic switch, a method which is still in use on the majority of the manually operated butt welders.

From 1890 to 1900 welding machines were introduced which generated their own supply of electric power. In the first type, a D.C. generator was built into the welder, and a low voltage, high capacity, direct current was used for welding. Subsequently machines appeared with A.C. generators, or alternators. Both types of machines had ideal magnitude control devices. Through the use of suitable field rheostats the welding voltage, and hence the welding current magnitude, could be continuously varied through wide ranges.

Soon after 1900, however, the resistance welders appeared with transformers again—this time with tapped primary coils. The use of the tapped primary enabled the user to adjust the welding voltage, and hence the secondary current magnitude, to the desired value. Due to its evident advantages and the development of industrial electric power systems, this method of magnitude control of the welding current has come to be universally adopted. Its main disadvantage comes from the excessive voltages across the entire primary coil when the line voltage is applied to the fewest number of primary turns. With care in construction and sound engineering design, this disadvantage may be minimized. An auxiliary auto-transformer may be used, however, if it is felt desirable to remove this condition.

In the manufacture of resistance welded pipe, it has been found advisable to secure closer regulation of the welding current magnitude than could be obtained with either the tapped primary transformer or auto-transformer alone. To achieve this result, a voltage regulator is inserted in the input side of the pipe welder. This, in conjunction with the welding transformer and possibly an auto-transformer, is used to obtain fine variations in the voltages applied to the welder. In this way a sensitive control of the welding current is obtained.

Thus, we see that the present methods of controlling the magnitude of the welding current are either the use of a tapped primary in the welding transformer, its combination with a potential regulator or the use of an auxiliary auto-transformer. Neither of these methods of magnitude control gives particularly delicate adjustments, and there is reason to believe that it may be necessary in designing for future special welding problems to devise methods of magnitude control which will give reasonably close adjustments of the welding current magnitude.

Development of Electric Power Control Devices for Spot and Projection Welders

It may be generally stated that as the size and extent of the metal section to be resistance welded decreases, the problems of controlling the welding current both in magnitude and time of application increase several fold. This is stated in partial explanation of why the development of modern control devices occurred in the improvement of spot welding methods. Early spot welders had no rigid requirements to meet. They were of small capacity and used a tapped primary transformer to regulate welding current magnitude. The current was either turned on manually or through the use of mechanical switches in series with the primary and attached close to the die and pressure developing mechanisms. The great majority of the work to be spot welded was of ferrous material, production was slow and visible evidence of welding was required. All these factors combined to make it unnecessary that the control devices should be particularly sensitive or accurate. If the manufacturer using spot welders was willing to disregard the marking of the work or demanded such visible evidence that a weld had taken place, the necessity for applying the welding current over short periods disappeared.

With the appearance of higher transformer voltages and the increasing demand for spot welders of larger capacity the control switches were used to operate a larger magnetic switch which in turn applied or cut off the power to the welder. This method was successful and is used at the present time for most of the larger manual or foot-operated spot welders.

High speed production and the demand for rapid spot welding methods brought new control problems. If the weld is to be made quickly it is evident that the time period of current application must be materially decreased. Instead of a two-second current application we have a fraction of a second. In order to weld the same material that we have previously been handling we must put approximately as much energy into the spot weld, and since the time has been decreased the power must be increased. Thus, the problem was to devise timing controls which would operate at the more rapid rates and handle the increased capacity. It was evident that they must be applied to power drive spot welders.

The small switches operated by the pressure develop-

ing mechanisms and in series with the primary of the welding transformer were first tried. These proved to be unable to handle the capacities required. They are successful in controlling currents not exceeding approximately 100 amp., but have the disadvantage of not offering much range of adjustment. The common practice, therefore, was to change the speed of operation of the spot welder. Through the use of separate large magnetic switches or contactors, as we shall call them, it was possible to materially increase the electrical capacity of the welders which this method would control. Two disadvantages existed, however: first, it was still difficult to adjust the time of application of the welding current to any extent, and, second, the large capacity contactors had definite limits of operating speed. Thus, a 300-amp. contactor cannot be used with a power-driven spot welder operating to produce a timing period of less than one fifth of a second. For power-driven spot welders operating at a moderate speed within the ability of the contactor to follow, this method of control is very successful and is in use today.

The first difficulty, namely, that of adjusting the timing period of the control switches, was eliminated by using a split cam-controlled switch, drum switch or similar devices. With these controls it was possible to adjust the timing from the maximum allowable period determined by the rate at which the power-driven spot welder was operating to the minimum period determined by the ability of the contactor to follow the timing speed.

The second disadvantage, namely, the inability of the contactor to operate at short time intervals, was eliminated by reverting again to mechanical switches on the spot welder in series with the primary of the welding transformer. This time, however, the switches were positively operated by split cams or some similar method. This method was found to be successful on spot welders up to a capacity drawing 200 amp. from the line. The disadvantage of this method of timing control was found in the fact that these types of switches did not break the welder current at the zero point in the alternation. As is known, alternating current passes through a zero value many times a second. Since the current was not being cut off at one of the zero intervals, it was found that at large capacities the switch would arc badly. This led to over-heating, and rapid destruction of the switch points followed. Two hundred amperes is the approximate limiting capacity of this type of switch, even with magnetic blowouts, for a power-driven spot welder operating on production.

It was felt desirable to retain the advantages which the power-driven switch in series with the transformer primary contained, and to eliminate the undesirable arcing. This was done by developing mechanical synchronous switches so constructed as to break the current to the spot welder at the interval when the current is passing through the zero point. This type of synchronous switch has taken many forms in the industry and its advantages are obvious. It has found its principal use in two distinct fields: first, for the control of large welder currents at rapid rates, and, second, for the timing of spot welds where extreme short periods of current application are desired. Its disadvantages are that it does not offer wide ranges of timing, is often difficult to set and requires careful adjustment to insure its opening at the proper point in the current wave.

Within the past few years modern alloy material, such as the stainless steel group, has made its appearance in production. Also, the users of spot welder equipment desired welds in which the stock was not marred by the welding process. These two factors made further refinements in the timing controls necessary. The projection method of spot welding was applied to the problem of non-marking of the work, but it was realized that the control devices which limited the period of application of the welding current should be more sensitive, have a higher degree of repetitive accuracy and be materially more flexible than the earlier equipment. To these ends the various power-driven mechanical synchronous switches were perfected in design, but the apparatus best meeting the requirements of an ideal timer was found to be a pure electrical timer. This equipment is the Thyratron. It will control a wide range of capacities and give accurate timing periods of from one cycle in the current alternations to several hundred.

In the previous description of the development of timing control devices it has been implied that the ideal timing mechanism was one which would measure out one cycle of welding power. In the case of a 60-cycle supply circuit this would mean a welding period of $^1/_{60}$ of a second. To some extent this is true, for one cycle of power applied to the welder carries the welding transformer through a normal operation. The flux density rises to the normal value for which the transformer was designed, and the maximum change in the total flux takes place. This change is closely sinusoidal and the output or the secondary welding voltage and current are also closely sinusoidal in wave form. Hence, the transformer's operating characteristics under the single-cycle application of power may be calculated by the usual methods. On this basis it would be indicated that if shorter welding periods were to be obtained higher frequencies in the power applied would be necessary. Thus, a 120-cycle supply would give a minimum timing period of $^1/_{120}$ of a second.

Mention should be made, however, of the possibility of using a fractional cycle period of power applied to the welder. As an illustration we might apply the power during the first half cycle of a 60-cycle supply. This gives timing in the primary circuit of the welder of $^1/_{120}$ of a second. Experimental work has been done in this direction and it is indicated that the method is sound. Possible revision of the methods of design of transformers used in this manner may be necessary.

At the present time the "shot" welding being done by the E. G. Budd Mfg. Co. is believed to fall into this class. They are welding with fractional cycle timing periods of current application.

Modern Control Equipment

There are several devices in use at the present time which merit individual attention. We will divide them into two classes. First, equipment which is operated by or controls the magnitude of the welding current, and, second, equipment which is used as or in conjunction with timing devices.

In the first group fall the tapped primary welding transformer, the voltage regulator and the auto-transformer, about which we have previously spoken. There are, however, devices which are operated by the magnitude or some function of the magnitude of the welding current. These we will list and describe:

A. The Thomson-Gibb Weld Monitor.—This is a visual indicator which operates when the welding current has reached a selected magnitude. During the process of making a spot weld, the welding current changes in magnitude from zero to some value which will fuse the metal between the welding points. This current sets up a magnetic field around the secondary conductors which varies in intensity as the current varies. The spot weld is completed by turning off the welding current at some predetermined point. The Weld Moni-

tor is adjusted so that it will indicate when the current has risen to the selected value. Its operation is dependent upon the changing field intensity around the secondary conductors as the current varies.

This instrument is best adapted to jobs where the secondary current rises relatively slowly in magnitude such as might be experienced in welding the heavier gages of scaly steel stock. Its disadvantages are that it is merely an indicator and depends upon the human element to complete the weld, and that it is erratic in operation on most non-ferrous materials.

B. The Roth Switch.—This is a mechanical switch magnetically controlled by changes in the welding current and voltage across the weld. It may be set to operate at any desired welding condition, and will turn off the welding current at the selected point in the welding operation. It is useful in the spot welding of sheet metal gages commonly used in production, but is limited for its best operation to the ferrous group of metals. Its chief disadvantage is in the fact that it is magnetically operated and, hence, has definite limits of operating speed. With large capacity spot welders it must be used to control a contactor which in turn will handle the welding current.

C. The Cutler-Hammer Control.—This device incorporates a small Thyratron tube to replace the small magnetic switch used in the Roth equipment. It is operated by a current transformer placed around one of the secondary conductors. It is quite accurate and has the advantage offered by the quick response of the Thyratron. It turns off the welding current at any selected magnitude. It is used in the same welding field as the Roth Switch, and recent experiments indicate that it will be successful with the non-ferrous group of metals.

The second group of devices, namely, those used for or in conjunction with timing apparatus, includes certain types of modern equipment which should be described:

A. Modern Contactors.—The contactors which have been furnished the resistance welding industry in the past years have been satisfactory largely because of the class of work which resistance welders were asked to do. At the present time, however, the usual type of contactor is not proving useful in many instances. They have several disadvantages. The moving parts are too heavy, they have definite limits of operating speeds which are much too slow, and with the gravity opening type there exists considerable variation in the period during which they are closed when controlled by regular constant operating intervals. One manufacturer—the Cutler-Hammer Corp.—has attempted to eliminate some of these disadvantages by developing an A.C. contactor controlled by direct current. It obtains its D.C. from rectifier tubes which are an integral part of the unit.

It is my opinion that the proper solution does not lie in this direction. The industry needs contactors with lighter moving parts in the larger capacity ranges, and a spring closure and *positive* magnetic opening would be an improvement. In the great majority of welding jobs the important problem in control is to know when to *turn the current off* and do it as quickly as possible. Precision in turning the current *on* is a minor matter.

B. The Cutler-Hammer Tube Timer.—This device offers automatic timing control over ranges running from approximately $^1/_{10}$ of a second to several seconds. It uses a small Thyratron tube and a condenser discharge circuit to obtain its control. It may be easily adjusted, has good repetitive accuracy and is very useful for controlling spot welders where definite time periods of current application are desired. It should not be used with scaly or dirty stock or with stock of uneven thickness.

Its chief disadvantage lies in the instability of the small Thyratron tube at temperatures below approximately 60 deg. Fahr. The manufacturer is eliminating this trouble, however, by using a heater element to keep the tube at a normal operating temperature.

C. The Thomson-Gibb Synchronous Interrupter and Contactor.—The synchronous interrupter is a mechanical switch which interrupts the welding current at selected rates and breaks it at the zero point in the alternation. It is successfully used in conjunction with seam or line welders and will handle capacities up to about 125 kv-a. Its chief disadvantage lies in its limited range of adjustment.

The synchronous contactor is a synchronous interrupter constructed to make only one closure at a time when tripped by the operator. It is used with spot welders and has a limited capacity of about 75 kv-a. Its chief disadvantages are those of the synchronous interrupter.

D. The General Electric Thyratron Control.—A complete description of this equipment and the theory of its operation will not be given here. It may be obtained from the G.E. folder GEA-1679 or from various papers, which have been presented before technical societies. Its advantages over other types of control equipment are: (*a*) Its adaptability. It may be used either as an interrupter for seam welding or as a spot welder timing control. (*b*) Its flexibility. As an interrupter, it gives wide variations of the ratio between the time on and time off periods. As a spot welding timer it gives quick and accurate adjustments of timing from one cycle to approximately 100 cycles. (*c*) Its mechanical simplicity. It has no moving parts. The only elements subject to wear are the tubes which have limiting periods of useful life. (*d*) Its absolute repetitive accuracy.

It is evident that in refinement the timing control equipment has greatly exceeded the devices used to regulate the magnitude of the welding current. In a sense this is understandable for, except for one class of work, the major control problem has always been to get the proper amount of heat into the weld. Since the heat is a function of time as well as current magnitude and since it was easier to design equipment which would control the time element with considerable refinement, it is natural that the development of control devices should be in this direction.

There is one class of jobs, however, where it is essential to make the weld in certain definite time limits. We find this class in the welding of the stainless steel group. The weld must be made and chilled rapidly in order to prevent the carbides from precipitating. For this class of work, it would seem that equipment is needed which gives a closer adjustment of secondary current magnitude than is now available.

The Disadvantages and History of A.C. Arc Welding

By C. J. HOLSLAG

✦Mr. Holslag is connected with the Electric Arc Cutting and Welding Company.

THE advance of alternating current arc welding has been steady and continuous. Transformer arc welders have low power factor. This power factor is about the same as that of an induction motor at part load and that is the way that motor generators are universally used for arc welding. Transformer welders use no power except when actually depositing metal, whereas a motor generator runs along at extremely low power factor when idle.

There is one disadvantage in alternating current welding other than the theoretical one mentioned above. If a transformer welder has not adequate power supply, it fails to give satisfactory service. There is no inertia to a transformer. During the War all plants were overloaded and the lowering of the capacity of a motor generator set was not as noticeable because of its inertia and electrical characteristics. Another disadvantage sometimes claimed for A.C. arc welding is that it is less insulated than a motor generator set. During the early days a few auto transformers and reactances with no insulation were foistered on the public by irresponsible proponents. It is quite simple with a magnetic switch to hold this voltage, whether welding or open circuited, to the voltage of the arc, that is, around 30 and 40 volts, whichever is desired, so that no shock can be obtained. Perhaps the ratio of A.C. to D.C. salesmen had something to do with the spread of the erroneous notion of the danger to shock from A.C. welding.

It is now generally accepted that the combination of A.C. welding, heavy current and covered electrodes is best for good work.

Alternating current shielded arc process is now accepted as the best method for welding Class 1 and 2 pressure vessels by those firms who have investigated all systems.

During the period that welding was judged by the operators' psychological reactions, direct current was more popular than alternating current, but where firms have really investigated strength and ductility, porosity, uniform results, ease of manipulation and adaptability to automatic work, first cost and cost of operation, they have adopted A.C. As a matter of fact, the covered electrodes and A.C. welding have helped each other to a commanding position.

In structural steel welding work important construction companies and railroads have adopted A.C. as have also a number of the important shipyards.

A little over twenty years ago the first A.C. arc welder was put out for use with covered electrodes. Thousands of these machines during the World War helped materially to provide a quick remedy in shipbuilding and industrial troubles. Unfortunately, in those days, due to the overdemand of power, all plant voltages were low. Unlike a motor generator which has some mechanical inertia, the A.C. welder is dependent on the power supply for its stability. When the voltage was unduly lowered, difficulty was experienced with the A.C. arc. With the proper power supply the A.C. energy is quite reliable and stable. The portability and flexibility of A.C. machines is due to mobility and the fact it can be wired from shop lines. Moreover, A.C. machines may be operated singly or together with equal efficiency. Of course, motor generators equipped with wheels are movable but not portable according to the dictionary.

The A.C. machine is 70 to 90% efficient when considered as a piece of electrical apparatus as compared with 50% efficiency in the motor generator set.

The A.C. arc is better for thin work especially the stainless series and the new A.C. hydrogen flame arc is better than either where applicable, such as in edgewise work, chrome, tungsten and molybdenum steel and where ductility is a necessity. No other arc welding method except very heavy covered electrodes shows any ductility worth mentioning. For heavy covered, medium and thin covered electrodes, in metallic arc welding, the A.C. arc is far superior to D.C., biting into and separating the slag or dross and keeping the puddle agitated and molten so that there is less chance of inclusions. X-ray pictures show this conclusively and proof will be gladly furnished on request.

Here is my theory on why A.C. is better than D.C. on heavy work. The best arc is one that has the smallest drops and on A.C., which reverses itself 120 times per second on 60 cycles, there can be no large drops. On D.C. the rod blobs itself off very frequently and causes trouble as shown by the Navy arcronograph. Rapid oscillation of the electrode will shake these drops smaller on D.C. but on A.C. the drops are so inherently small that the transference seems always to be a vapor transition.

The D.C. arc is better for fussy jobs such as thin tube or boiler repairs, because of the greater and finer control possible with D.C. and because A.C. is faster melting at the same current. However, A.C. has no arc blow and will go to the edge of a plate, into a corner or to the bottom of a fillet.

The Wirt-Jones test made with A.C. in 1918 in which all test pieces broke outside the weld in 60,000-lb. boiler plate, still stands unassailed as good a job as has ever been done with arc welding and these were all done with A.C. and all the test pieces broke outside the weld.

D.C. is better for bronze and copper alloys and its stainless steels and, while A.C. and D.C. divide the nickel and chrome series between them, D.C. is slightly better for monel and nickel alloys and A.C. where chrome is the deciding factor. For aluminum welding A.C. gives better welding results than D.C.

As to cost, the first installation and operation is less for A.C. by a wide margin. The first cost is further lessened in A.C. welding where a large transformer is used in conjunction with several reactors, one for each operator. Such a system can be used with extra cost on A.C., but if a large motor generator D.C. set is used to feed several operators separated by resistance, there is a further very large loss in the resistance controls.

By means of three-phase distributing transformers the load can be divided. We manufacture a combination in which one or two D.C. arcs and two or three A.C. arcs can be had from the same machine at a small additional cost.

Carbon arc cutting with the carbon or graphite electrode is more cheaply done with A.C.

Of course, where reverse polarity is essential to success, such as in bronze welding, D.C. is necessary, but for general use in iron or steel there is no need for this polarity difference.

Shear Distribution at Junction of Beam Weld to Column

By S. C. HOLLISTER AND R. H. WOOD

✦Paper presented at Fall Meeting, A. W. S., October 2 to 6, 1933, by S. C. Hollister, Professor of Structural Engineering, Purdue University, and R. H. Wood, graduate student of Purdue University, connected with the bridge department of the Mississippi State Highway Department. Report presented to Fundamental Research Committee of American Bureau of Welding.

WHEN the web of a beam is attached by fillet welding to the face of a column, the connection is designed on the basis that the shear is uniform per linear inch of fillet. It is important to know whether the distribution of shear stress at such an attachment is really uniform or whether it is disposed in some other manner. It is the purpose of the present paper to discuss a photoelastic study of such shear distribution and to report the results obtained.

The specimen used for the test consisted of a beam monolithically attached to the column, as shown in Fig. 1. The specimen was cut from one sheet of material $^1/_4$ in. thick. The beam strands studied varied from $1^1/_2$ to 2 in., and the depth varied from $^1/_2$ to $^3/_4$ in.

Three types of loading were employed: 1. A central concentrated load was applied by means of a roller, as shown in Fig. 1. 2. A loading approximating a uniformly distributed load was obtained by placing an elastic rubber mat between the steel loading plate and the top edge of the beam. Although this load was not precisely uniformly disposed on the beam, it closely approximated this condition. It is referred to throughout this paper as the "elastic loading." 3. The third method of loading produced bearing on the beam near the ends, accomplished by placing the steel loading plate directly in contact with the beam. As the beam deflected somewhat under load, the pressure of the steel plate was removed throughout the central portion of the beam, but contact was maintained over a considerable portion of the length near the ends, as will be noted later. This third method of loading is for convenience called the "shear loading" throughout the paper.

The lines of principal stress in the beam and in the portion of the column near the attachment of the beam to it are shown on Fig. 2 for the three types of loading. The elastic loading indicates a state of varying amount of flexure along the length of the beam. The concentrated load shows the effect of the load itself in producing a stress congestion immediately under the load. The form of pattern of the principal stresses for the shear loading indicates that this loading produced a varying flexure for a distance of approximately the depth of the beam out from the face of the column, with the remainder of the beam under a constant bending moment.

It should be recalled that the lines of principal stress indicate the direction of maximum tension and maximum compression existing at all points in the member. The lines of principal stress act perpendicular to one another and are the resultants at every point of both flexural and shear stresses. The lines of principal compression can be identified readily by the horizontal direction they take near the top face of the beam, whereas the principal tensions take a horizontal direction near the bottom face of the beam.

At any point in a beam there exists a pair of planes at right angles to each other upon which the shear is a maximum. These lines of maximum shear are also shown on Fig. 2 for the three types of loading used in this investigation. These lines of maximum shear make an angle of 45 deg. with the lines of principal stress at any point.

The shear distribution on the vertical plane of attachment between web and column is shown at the top of Fig. 3 for the three conditions of loading and for four different depths of beam. The average shear is also plotted on each figure as a rectangle for ready comparison. It will be noted that the concentrated and elastic loadings produced shear distributions close to uniform distributions over the depth of the beam. The so-called "shear loading," however, produced a high shear concentration near the top face of the beam reaching in two instances the value of twice the value of the average shear.

A second series of specimens was prepared in which the beams were attached to the column for only a part of the

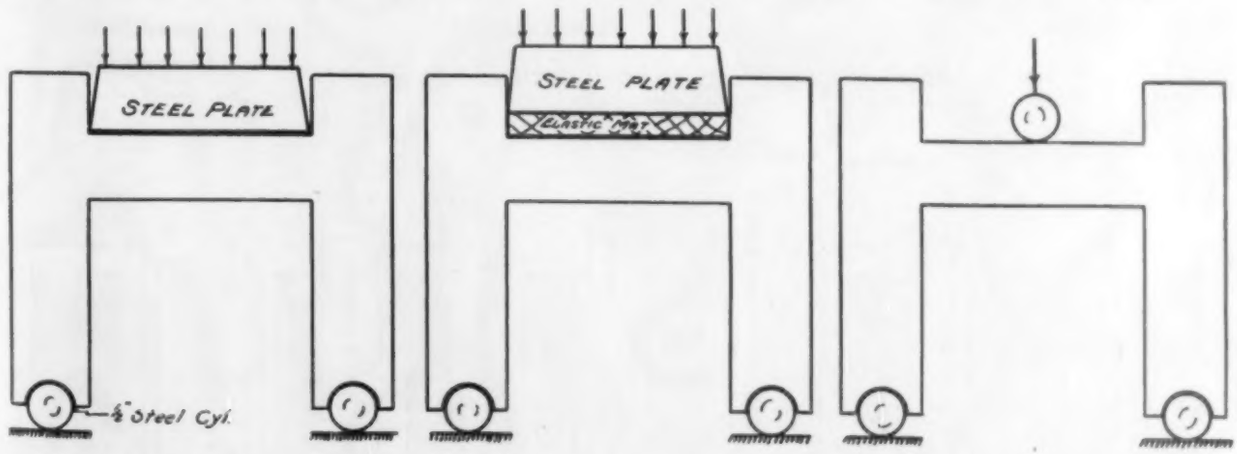

Fig. 1—Loading Arrangements

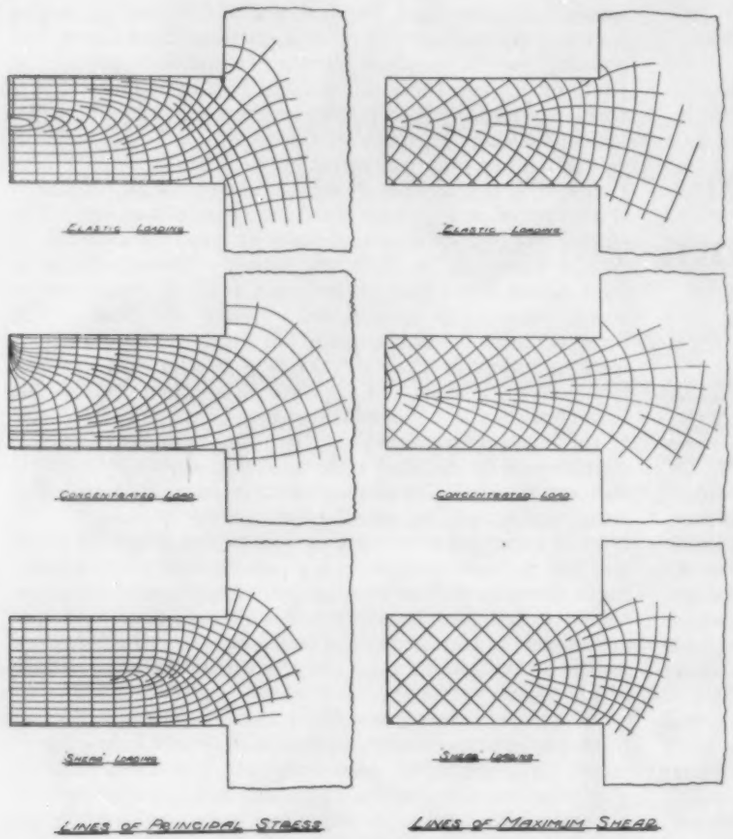

Fig. 2—Lines of Principal Stress in the Beam and in the Portion of the Column Near the Attachment of the Beam to It for Three Types of Loading

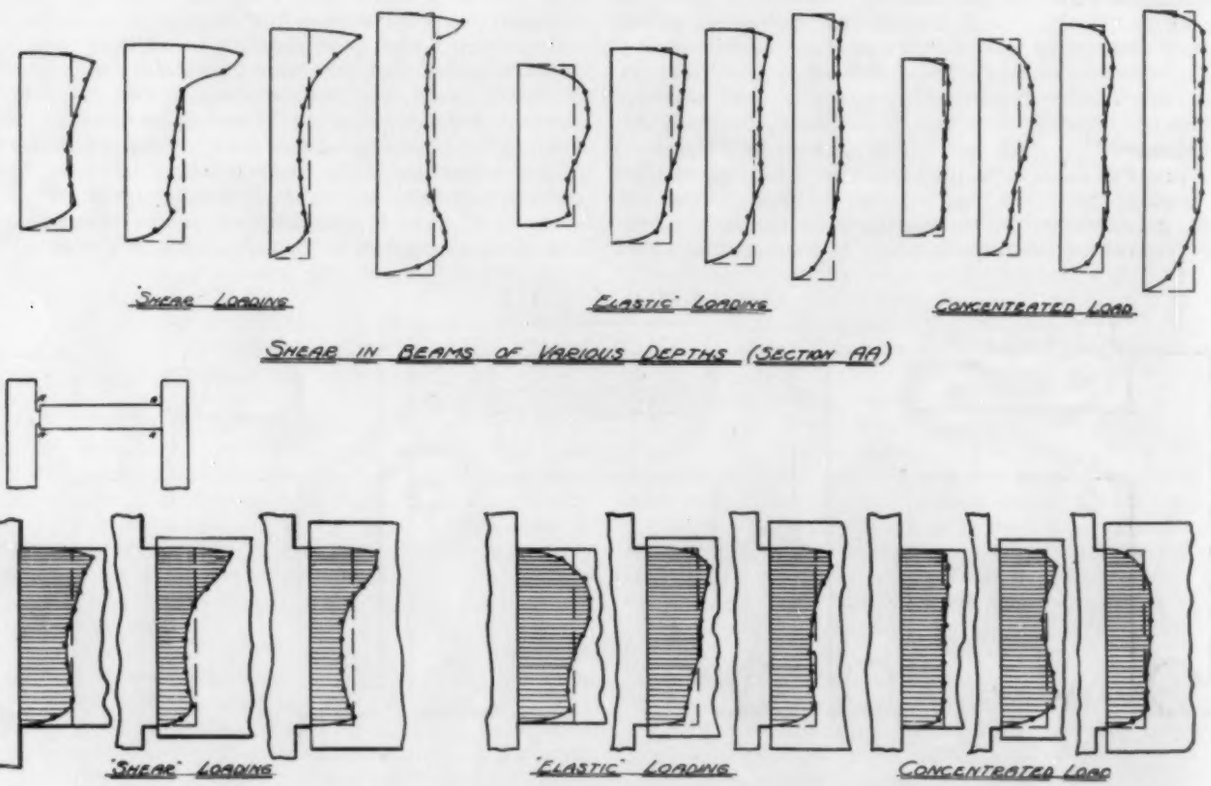

Fig. 3

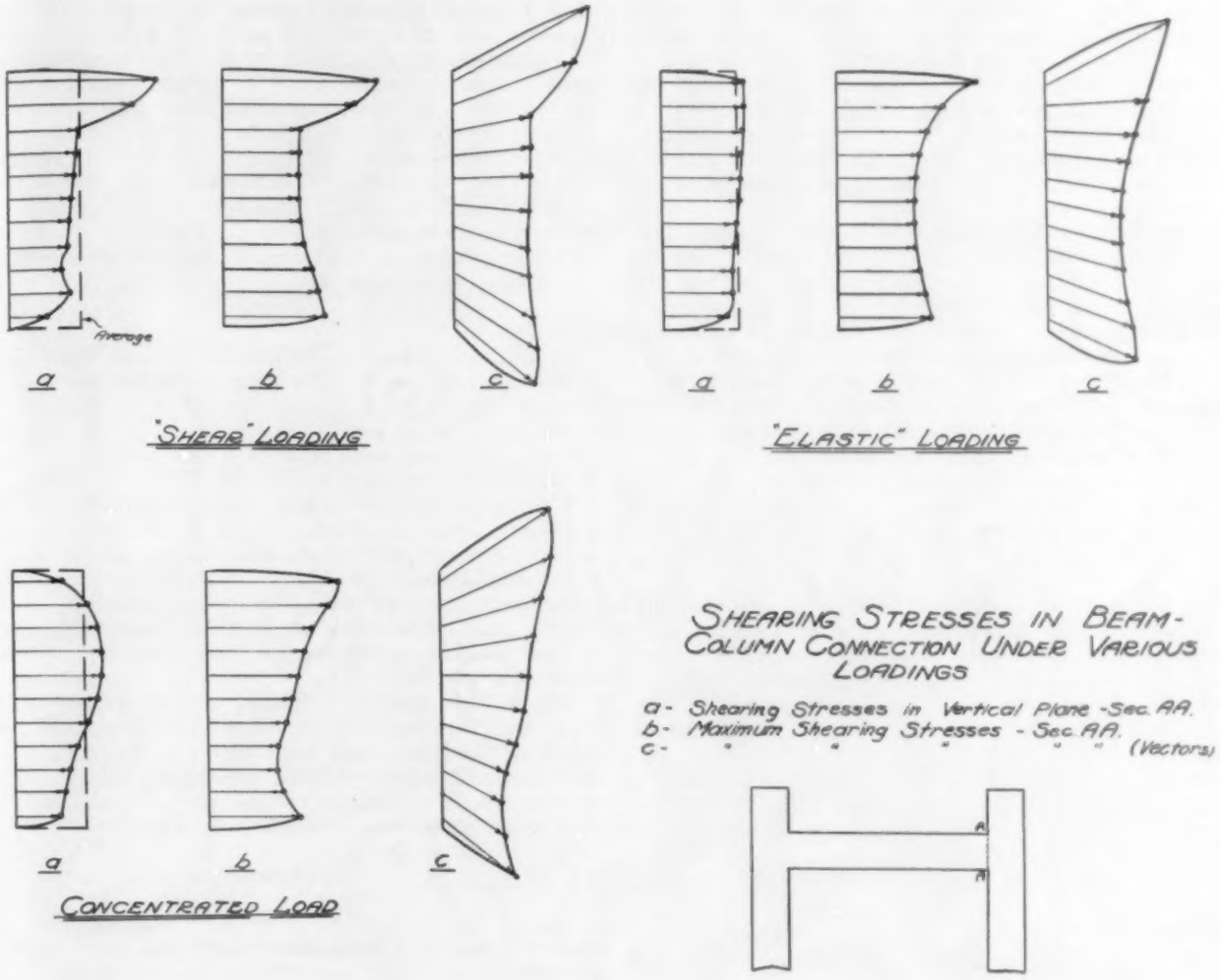
Average
a
b
c
"SHEAR" LOADING
a
b
c
"ELASTIC" LOADING
a
b
c
CONCENTRATED LOAD
SHEARING STRESSES IN BEAM-COLUMN CONNECTION UNDER VARIOUS LOADINGS
a- Shearing Stresses in Vertical Plane -Sec. AA.
b- Maximum Shearing Stresses - Sec. AA.
c- " " " " " (Vectors)
A
A

Fig. 4

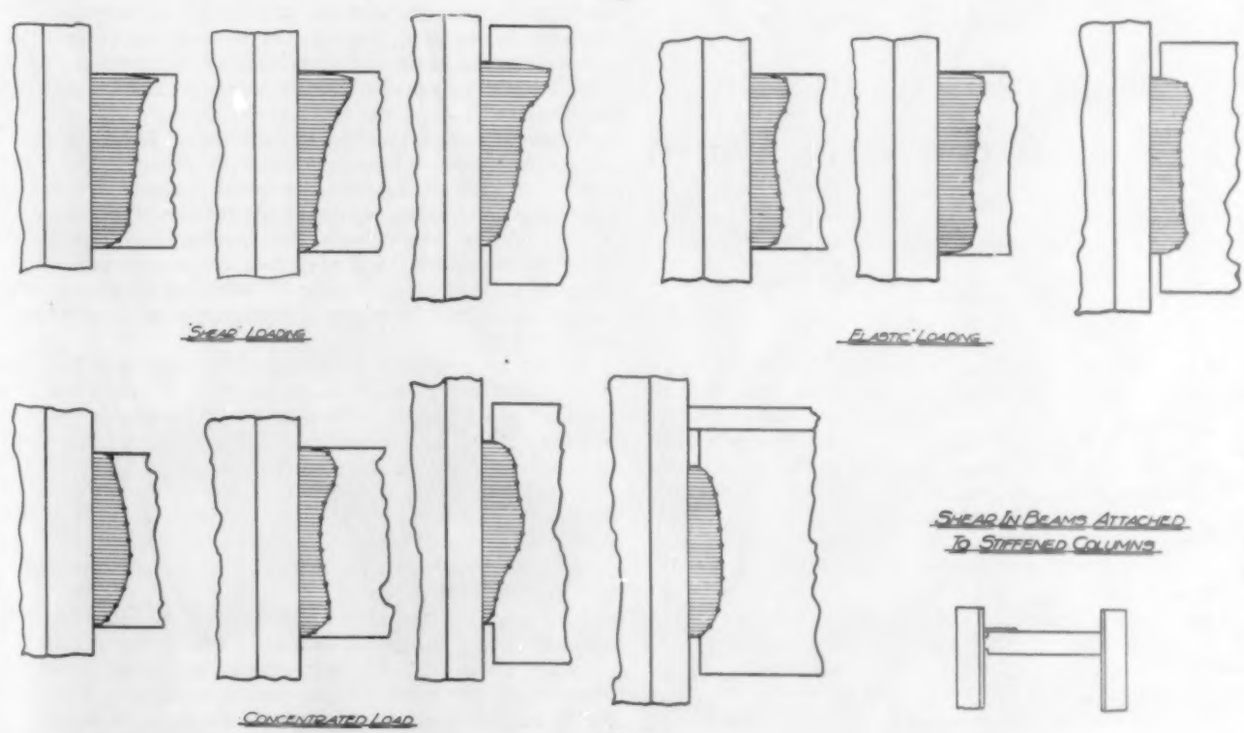
'SHEAR' LOADING
ELASTIC' LOADING
CONCENTRATED LOAD
SHEAR IN BEAMS ATTACHED TO STIFFENED COLUMNS

Fig. 5

depth. This is a frequent condition in practical structural welding. The shear distribution over the vertical plane of attachment to the column is shown at the bottom of Fig. 3 in comparison with a beam not so notched. All three conditions of loading are again represented. It will be noted that the shear at least was not enhanced by the presence of the notch, the form of the shear distribution diagram being similar in character whether the beam is fully or only partially welded.

A study of the lines of maximum shear of Fig. 2 indicates that the maximum shear is on a vertical plane at about the mid-point of the depth of the beam, but that it is inclined considerably from the vertical at the top and bottom faces of the beam. It is of some importance to determine the magnitude of the maximum shear as well as its direction for all points lying along the plane of attachment of the end of the web to the column. Figure 4*c* shows by means of vectors the direction and magnitude of the maximum shear at various points along the plane of attachment of beam to column, for the three conditions of loadings studied. It will be seen that in every case the maximum shear occurs at the top and bottom faces of the beam, and at angles of considerable slope.

For purposes of ready comparison, Fig. 4*b* was constructed from Fig. 4*c* by rotating all vectors to horizontal positions, and at the same time preserving their magnitude. These may now be readily compared with Fig. 4*a* which was repeated from Fig. 3 and which shows the shear distribution in a *vertical direction* on the same plane.

Since the shear distribution is a function of the relative elastic yielding of the web and of the column, it would be of interest to see what effect upon the shear distribution the presence of a column flange would produce. Figure 5 shows a set of models prepared with a flange against which the beam is attached. It should be noted that the beam is attached to the column in the plane of the web of the column. The distribution of shear was shown for the several types of loading, both when the beam is fully attached and when it is only partially attached over the end section. It should be noted that in the case of the so-called "shear loading," the effect of the flange is to reduce the shear intensity near the bottom of the beam and thereby to make the concentration near the top face of the beam more marked.

Conclusions

In all cases of loading the maximum shear was found to be near the top face of the beam in a region where high tension also exists. It is, therefore, of great importance to relieve as far as possible participation by the web in the transfer of moment stresses. This is accomplished by attachment of flange to column.

When a large part of the load comes on the beam within a distance from the column equal to the depth of the beam, the shear distribution diagram approaches a triangle with a maximum shear intensity at the top of the attachment equal to twice the average shear intensity. Special precautions, therefore, should be taken in the case of short brackets and beams receiving their load close to their end.

Beams with distributed loading or with concentrated loads placed on the beam at a greater distance than the depth of the beam, may be designed as having a uniformly distributed shear distribution at the end, provided adequate accommodation of the moment stresses has been provided by means of flange attachment.

Automatic Carbon Arc Welding in the Automotive Field

By **A. F. DAVIS**

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THE use of carbon arc automatic welders in the automotive field has increased by leaps and bounds since the introduction of the process some 10 years ago. Today the number of applications is almost unlimited. New adaptations are being made constantly. In the November issue of the JOURNAL OF THE AMERICAN WELDING SOCIETY, Mr. Claude Bowlus, in his article "Welding in the Automotive Industry," makes this statement: "By far the greater portion of the arc welding has been done with the metal arc, although some applications have warranted the use of the carbon arc in which adjacent areas of parent metal are fused to form the weld." The writer disagrees with this statement. Most observers would say that there are many more applications of automatic carbon arc welding than of the metallic arc. In this article some of these uses will be discussed, together with the results that may be expected.

The factor which determines the use of the automatic welding process is almost invariably economic. The designer or engineer, hoping to lower unit cost and at the same time maintain the standards of his product, specifies the process as the proper solution for the problem involved.

Progress in this method of fabrication has been rapid in recent years. Improvements in the process have been made which increase the speed of operation and at the same time insure uniform production of good sound welds. A few years back the process may have been more limited than it is today, but its scope has been increased so that it now may be adapted to almost any production problem where a continuous or intermittent seam is made.

It is now generally accepted that weld metal of the most desirable physical characteristics is produced in a shielded arc and this process is doubly valuable because of the tremendous increase in welding speeds. It is common knowledge that molten steel has an affinity for oxygen and nitrogen and when exposed to air enters into chemical combinations with these gases to form oxides and nitrides in the steel. These impurities tend to weaken and embrittle the steel as well as lessen its resistance to corrosion.

In the ordinary arc the molten metal is exposed to the ambient atmosphere, containing chiefly oxygen and nitrogen. To protect the arc it must be shielded and we can do this by enveloping it in a completely inert gas. Welds so made are largely free of damaging oxides and nitrides and have excellent physical characteristics. The

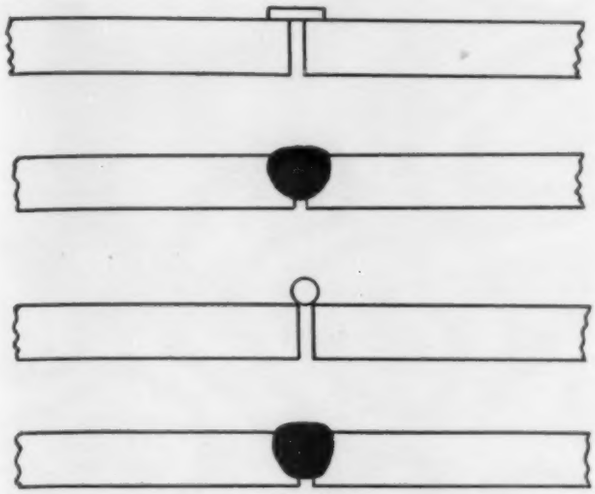

Fig. 1—How Filler Metal Is Laid on the Joint and Fused into the Weld

tensile strength will be from 60,000 to 80,000 lb. per sq. in., the ductility between 20 and 30 per cent in 2 in. and resistance to corrosion better than mild steel. Welds made in an unshielded arc will have tensile strength 20 to 50 per cent lower, much less ductility and inferior resistance to corrosion. Welds made in a shielded arc can be made with higher current, hence, better fusion and greater speed of operation. The result is that almost every really economical automatic arc welding application utilizes the shielded arc process.

The common butt weld is one of the more widely used methods of joining steel, but there are many types. With extremely light metal, 20 to 14 gage, as used on tanks, small containers and so forth, it has been found most economical to turn up the edges of the material to meet the arc and then clamp the work on a copper backing. It is possible to attain a welding speed of 140 ft. per hr. on 18-gage metal which has been prepared for welding by turning up the edges to meet the arc, these edges melting down to supply the weld metal.

For butt welds without added filler metal it is possible to set the welding generator for greater heat, and speeds of 150 ft. per hr. can be reached on $^{3}/_{16}$-in. plate and 100 ft. per hr. on $^{5}/_{16}$-in. plate. Common applications of this process on this type metal are found in the manufacture of small parts, rear axle housings and tubes for the automotive industries, ship channels, generator frames and the like.

Figure 1 shows how extra metal is laid on the joint and how it is fused into the weld. This filler metal can be tacked in position, supplied manually or fed into the arc automatically. The last-named method is preferable. With filler metal added, typical speeds for butt welds are 140 ft. per hr. for $^{3}/_{16}$ in. and 90 ft. per hr. for $^{5}/_{16}$ in.

Plain butt joints in plates up to $^{3}/_{4}$ in. thickness can be automatically welded by the shielded carbon arc. The welding speeds attained in welding this type of joint in plates for which the process is best adapted are far greater than those of any other fusion welding process.

It should be borne in mind that speeds and costs given in this article are for a high quality shielded arc weld and should not be compared with processes which do not give this high quality. As a general statement it may be said that for equal quality the speeds and costs of this method cannot be equaled by other arc processes.

Rear axle housings, chassis frames, wire wheel hubs, tire carrier brackets, disc wheels, mufflers, brake equalizer shafts, torque tubes and generator housings are some of the automotive parts in whose manufacture arc welding plays an important rôle. These products offer typical examples of the application of automatic arc welding.

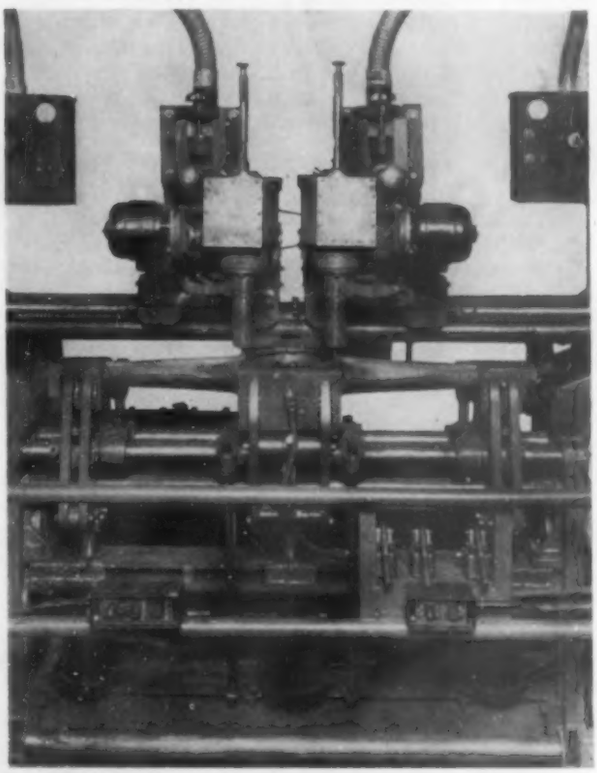

Fig. 3—Mounting for Two Automatic Welding Heads Which Employ the Shielded Arc to Weld Rear Axle Housings

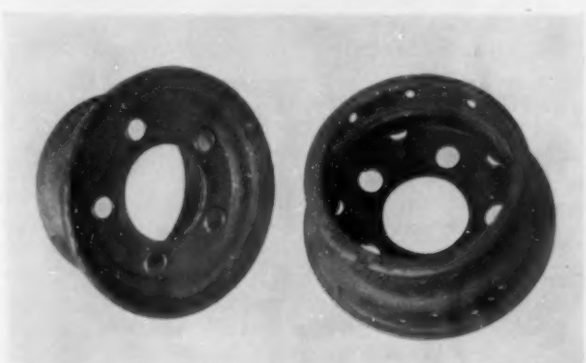

Fig. 2—Wire Wheel Hub at Left Is Edge Welded; at Right Lap Welded

Wire wheel hubs consist of two steel stampings fused into each other by the electric arc. In one type of hub the component parts, when assembled, form a lap joint around the inner circumference of the hub. This is automatically welded with a shielded carbon arc without the use of additional filler metal. A welded hub of this type is shown at the right in Fig. 2. The weld around the circumference of the 8-in. hub is made in 40 sec. The floor to floor production is 50 wheels per hr. on the automatic welder. The specimen shown at the right was subjected to a very severe test in that sufficient pressure was put on the inside until the metal started to fail through the row of holes as shown, however, no sign of any stress on the weld was indicated.

Another type of wire wheel hub, whose parts when assembled form an edge joint, is automatically welded with a shielded carbon arc. The welded hub is shown at the left in Fig. 2. It is welded at the rate of 60 hubs per hr. On both the hub welders the welding head is stationary, the work being revolved under the arc. The fixture which holds the work on the latter machine is swivel-mounted to permit welding of both edge and lap joints.

The banjo-type rear axle housing is composed of two identical stampings which, when placed in the holding fixture for welding, form two parallel longitudinal butt joints 180 deg. apart. These stampings are prepared for welding in the last striking operation which coins the edges forming the butt joint. These coined edges provide the necessary filler metal for welding the butt joint.

The rear axle housings are welded by the machine, Fig. 3, which operates as follows:

The two stampings which comprise the housing are clamped into a fixture and placed under the two arcs. The two arcs are struck simultaneously and they are held for a second in order to secure proper penetration. Then the carriage motor is engaged and the heads are moved in opposite directions to the end of the housing. Here the arc is broken and the heads automatically return to their original position. The fixture is then reversed and the opposite side of the housing welded in the same manner.

Floor-to-floor production averages 25 housings per hr. with the machine illustrated. Generally, such machines

Fig. 6—Production Line Scene Showing Automatic Machines Welding Torque Tubes

Fig. 4—Longitudinal Welds in These Rear Axle Housings Were Made Automatically

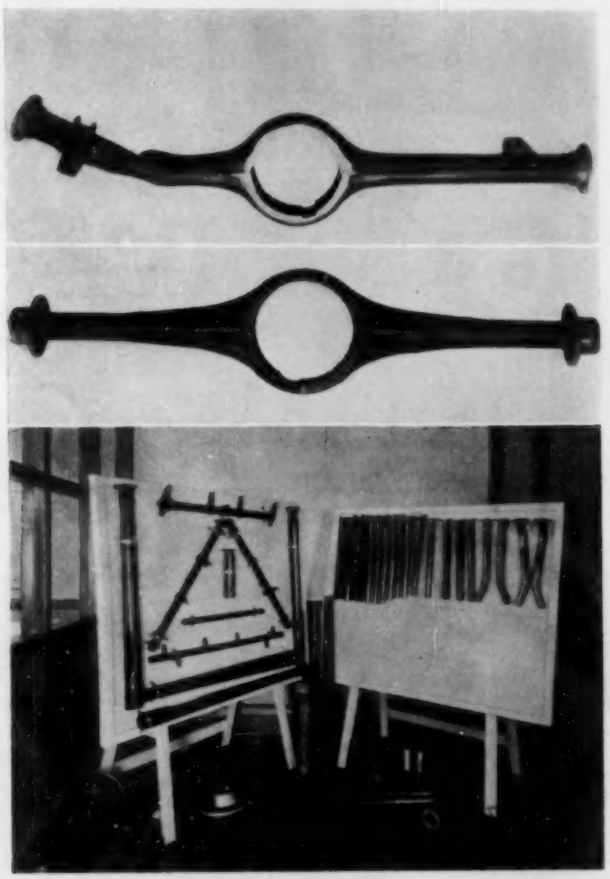

Fig. 5—Tubular Parts Made of Strip Steel Formed into Tubes and Automatically Welded with a Shielded Carbon Arc. At Right are Shown Progressive Steps in Fabricating a Tire Carrier Tube

are installed in pairs with machines facing each other. On such installations one man operates the two machines. Two 400-amp. welding generators supply the current to each machine.

Welded housings are shown in Fig. 4. The upper housing was twisted in an attempt to fracture the welds. The spring supports on this housing are welded in place by the manual process with a metallic arc.

Tubular parts such as torque tubes, cross shafts and tire carriers are being manufactured most economically by the shielded carbon arc process of automatic welding. Tubular parts so made are stronger, lighter and of uniform wall thickness. The fabricated tube can be designed to have the exact required weight for all sections of its length. No excess material is required to provide for swaging as this operation is not required in the fabricated tube. A 10 to 50 per cent saving is effected in material cost, the exact amount of saving being dependent on the analysis of the steel and type of tube. The arc-welded tubular parts are made from strip steel formed into tubular shape with a longitudinal butt joint. This is welded automatically by the shielded carbon arc process.

Where required tubular parts are upset at the ends after welding. Figure 5 shows a group of tire carrier, torque and cross shaft tubes. The panel board at the right shows the progressive steps in the manufacture of a tire carrier tube. The original wall thickness is 0.093 in. and the turned-up flange on the ends has a thickness of approximately 0.250 in. These tubes have been upset to $^{3}/_{8}$ in.—the equivalent of thickening the walls four times—without splitting the weld.

Actual welding of tubular parts is shown in progress in Fig. 6. The welding machines shown in this illustration are equipped with automatic shielded carbon arc welding heads with beam mounted carriages which are propelled

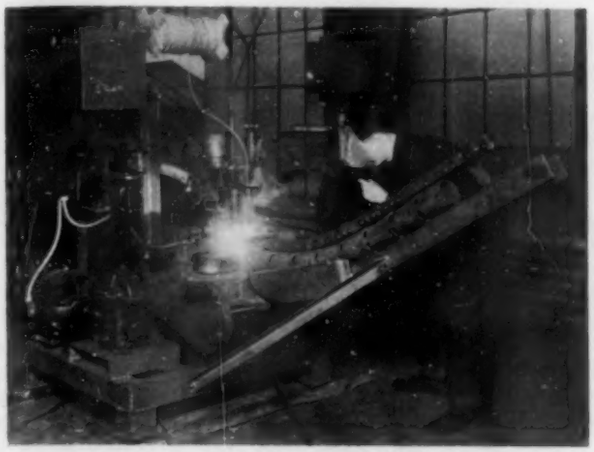

Fig. 7—This Automatic Welder Welds Generator Frames with a Shielded Carbon Arc

along the overhead beam carrying the arc over the work which is clamped over mandrels. Depending upon length, two to four tubes are welded in line. The welding is done in one direction, the heads returning rapidly to starting point after weld is completed.

On certain types of tubular products, such as torque tubes, the automatic shielded carbon arc welding heads are stationary, the work being fed in a continuous line underneath the arc.

Floor-to-floor production is dependent on the length and thickness of tubing welded. One plant equipped with fourteen automatic shielded carbon arc welding machines maintains an average weld production of 1000 tubes per hr. for 20-hr. working days. Tubes in this particular plant are produced in lengths from 14 to 50 in. having 0.093 in. to 0.375 in. wall thickness.

Generator frames might also be classified as tubular parts. These are fabricated of $^5/_{16}$ or $^3/_8$-in. steel plate. A rectangular piece of steel plate is formed into a cylinder with adjacent edges forming a butt joint. The cylinders thus formed are fed, with butt joints up, by gravity under a stationary automatic welding head. The edges forming the butt are squeezed tightly together as they pass under the shielded carbon arc which automatically welds the joint.

The automatic machine shown in Fig. 7 automatically welds the generator frames at the rate of 240 per hr. Note that the cylinders are in position on the gravity feeder ready for welding. The welded frames are automatically expelled from the machine after the welding operation is completed.

Figure 8 shows an automatic carbon arc welder for welding the longitudinal seams on mufflers. Figure 9 shows a similar automatic for welding the muffler ends.

In Fig. 10 is illustrated an automatic welder equipped with an electronic tornado welding head for welding frames. These frames utilize channels welded toe to toe to form a box section.

In connection with these applications, it should be stated that there is no tendency for the arc to shift from its path with such automatic welders.

The photographs and examples cited in this article are intended to indicate the variety of uses to which the automatic carbon arc is being put today in the automotive industries. There are many applications other than those described here.

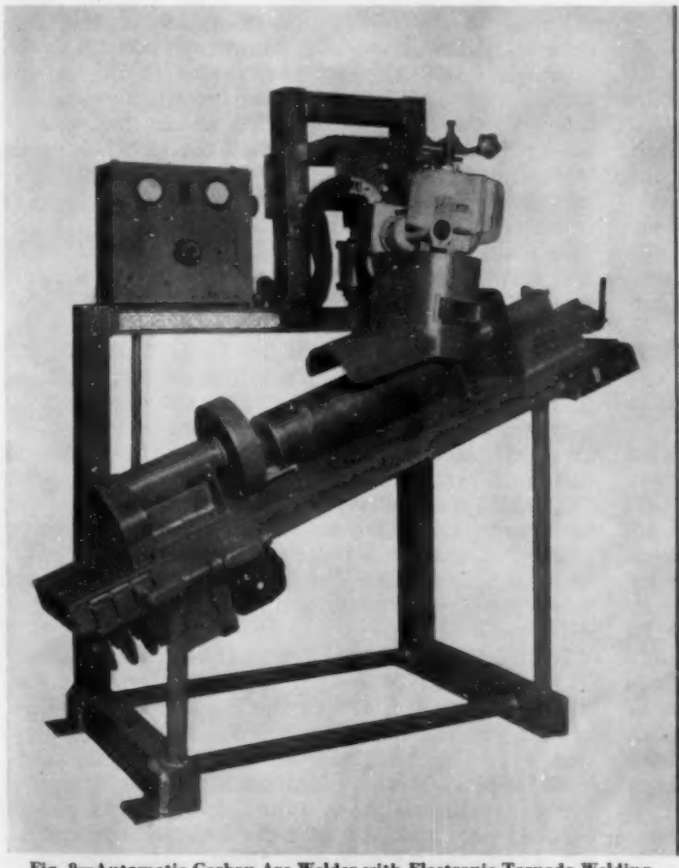

Fig. 8—Automatic Carbon Arc Welder with Electronic Tornado Welding Head for Welding Longitudinal Seams on Mufflers

Fig. 9—Automatic Machine for Welding Muffler Ends

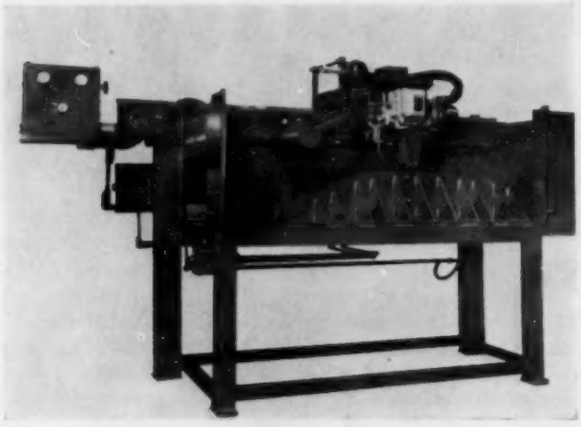

Fig. 10—This Machine Automatically Welds Side Frames with a Shielded Carbon Arc

Mr. Bowlus in the article already referred to says: "There has been developed within recent months a welding head adapted to feed the fully shielded arc rod and in the light of present development we can safely predict the application of arc deposits on fully automatic machines superior to the metal from which frames and body stamping are being fabricated." As pointed out above, welds made properly are much superior in physical characteristics to the base metal used. And such welds have been made regularly for several years by progressive manufacturers; and further, Mr. Bowlus makes this statement: "It is not impossible that frames and other parts will be welded automatically and the use of riveting will be entirely superseded by combination of various methods, or a single process of welding." Frames are being automatically welded today. This is not a dream of the future but an actuality. There are few production jobs requiring welding where the shielded automatic carbon arc process is not practical and economical.

Fatigue of Metals

By G. E. THORNTON

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SOME attention had been given to "Fatigue of Metals" as early as 1829, but it was not until 1881 that scientific investigators became interested in presenting a theory of failure of metals when subjected to repeated stresses.

From time to time since that date many theories have been advanced to explain Fatigue of Metals. In the beginning, since metals were considered of a fibrous nature, these theories were along lines which were different from those theories which were built up around the crystalline formation of metals. A great many of the later theories have much in common, but some of them are totally dissimilar to anything presented previous to their appearance.

In presenting a theory of what is commonly called Fatigue many difficulties present themselves. These theories may be proved by known phenomena to a certain stage in their development and from there on assumptions made to complete the theory. Because of these assumptions it is difficult to say that the theory is true and equally as difficult to say that it is not true.

A fundamental theory of Fatigue will some day be advanced which will stand the onslaught of scientific investigators. This theory will be consistent with the laws of molecular physics and with all proved data of the behavior of crystalline aggregates and single crystals and equally with non-crystalline materials. This theory will withstand the most rigorous experimental investigation.

In recent years the advent of high speed machinery has increased the interest of investigation into the field of Fatigue. Members under vibration have failed when the applied stress was figured as safe. Alloy steels used in automobile and aircraft construction have demonstrated the destructive effect of vibration with attendant fatigue.

Several years ago the United States Navy was threatening to abandon the use of welding in the construction of naval aircraft. The Boiler Code Commission of New York refused to permit welded, fired, pressure vessels. The welding companies sought the aid of scientific investigators and set up experimental works in seeking a way out. The scientific investigator, working hand in hand with industrial experimentation, has so increased the strength of welded metals that welding is now permitted in the construction of fired pressure vessels; it is used in bridge construction, airplane work and countless thousands of other places where strength is a determining factor in construction.

When a comparison is made between a welded joint and a riveted joint either from the standpoint of strength or cost of fabrication, the decision has nearly always been on the side of the welded joint. In later years with the cooperation of the steel companies in putting out rolled shapes suitable for welding, the cost of fabrication by welding has shown a still greater decrease.

In testing welded metals, the tests in tension, compression and shear have compared very favorably with the same type of metal not welded. In fatigue tests the welded metals have never compared favorably with the same metal not welded except in the last two or three years. In this time three or four companies have so improved their technique of welding that welded samples have very closely approached results of the parent metal in fatigue endurance.

In determining ways and means of bringing up the endurance limit of welded metals investigations were started seven years ago by the Engineering Experiment Station at the State College of Washington in cooperation with the American Bureau of Welding of New York and its affiliated industrial companies.

Previous investigators in the field of Fatigue of Metals conclusively proved that blow holes, small cracks or pits in the metal presented points of highly localized stress. These localized stresses very quickly rupture

Fig. 1—A Bank of Six Farmer Type Rotating Beam Fatigue Machines in the Experimental Laboratory

Fig. 2—Close-Up of Farmer Type Rotating Beam Fatigue Machine. Fabricated by Means of Welding and Then Machined to Take Motor and Bearing Assembly

the metal at that point and this rupture was apparent in the form of a minute crack. Once a minute crack is formed, the metal progresses rapidly to complete failure.

Micrographs, X-rays and other means of examination show us that welded areas when not properly formed are weakened by the presence of blow holes, cold shuts, spots of burned metal and cracks due to poor bond between the weld metal and parent metal. These points immediately present points of highly localized stresses and in the fatigue tests these points progress rapidly to a complete failure. Since the original metal does not usually contain so many defects, it is apparent that its endurance limit would be much higher than the welded metal.

After many tests of welded samples we were of the opinion that the three primary causes of welded metals failing prematurely in fatigue were:

1. The presence of pits, cracks and burned metal.
2. The presence of areas of extremely large and small crystals adjacent to each other.
3. The extreme differences in hardness between the weld metal and the adjacent parent metal.

The following figures will give you a picture of our work at the State College of Washington.

It is well to mention here that 10,000,000 revolutions are assumed as a point at which we are safe in stopping the tests. This number of revolutions is sufficient for making a fairly close analysis of what is going to happen within safe stresses. Many of the tests performed in the beginning ran into 40 or 50 millions of revolutions for each specimen, taking about 15 to 20 days for each specimen. This told us no more regarding that metal as far as its endurance limit is concerned than we were able to predict by watching its behavior up to 10 millions of revolutions under varied stresses.

In many hundreds of specimens tested we found that if the ordinary specimen lasted 10,000,000 cycles or revolutions it would go on at that stress indefinitely except at points very close to the endurance limit. At points close to the endurance limit we found some specimens breaking above and some a very short distance below the average endurance limit. In all the specimens tested I doubt if there were over a dozen and a half that broke above the 10,000,000 mark when the long time tests were being run.

At present we are stopping the tests at the 10,000,000 revolutions point.

The following figures will show why welded metals fail to have the endurance limit of the same metal not welded and compare the two in endurance limit.

These figures are from micrographs of fire-box steel and were made at 750 diameters.

Figure 5. S. N. Diagram of resistance and flash welds, showing endurance limit of welded metal in comparison to the endurance limit of that same metal cut directly from the plate. These samples were made by the resistance or flash method when two pieces of metal were placed end to end and the current turned on. The action of the arc in expelling the air from the welding area has prevented the formation of oxides in this area. While the metal at the point of contact is at a white or welding heat the metal is forced together by a slight forward movement of the machine parts gripping the metal to be welded. This pressure prevents the formation of large grains or crystals in the cooling metal as shown by the next figure.

Figure 7 gives the endurance limit of atomic hydrogen welds compared to endurance limit of the same plate not welded. These samples were not representative of

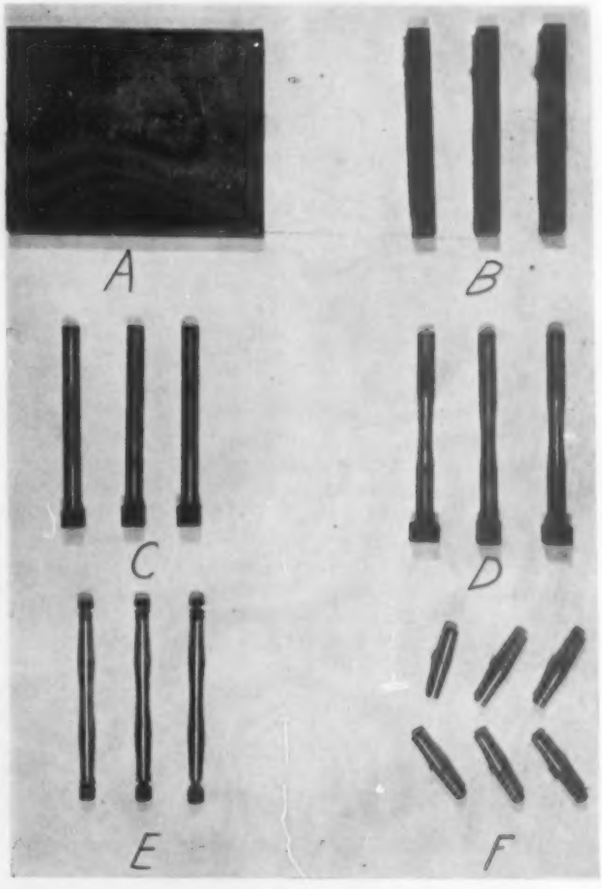


Fig. 3—Preparation of Fatigue Specimens. Welded Coupons Were Received from Industrial Companies and Sawed into Bars One Inch Square. These Bars with the Weld Midway between the Ends Were Machined, Polished and Tested

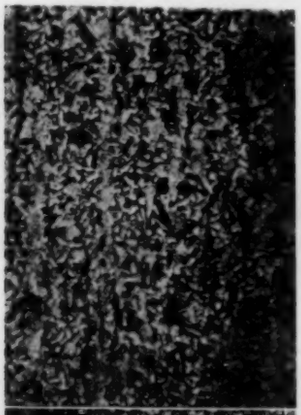


Fig. 4—Fire-Box Steel Not Welded. Note the Arrangement of Lines of Ferrite and Pearlite from the Rolling Operation in Making the Plate. This Steel Is Fire-Box Steel, 1520 S. A. E. Specification and Contains Manganese and Carbon

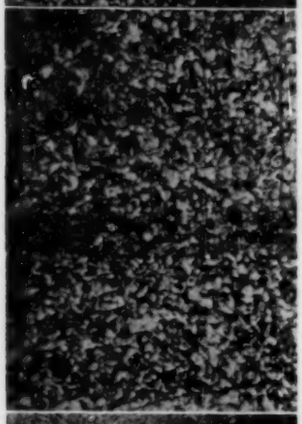


Fig. 6—Showing Grain Structure of Flash Welds. The Vertical Line of Small Grains through the Center of the Picture Represents the Weld Line on This Type of Welding

Fig. 8

atomic welds since that process is not intended for three-quarter-inch steel but is usually used on thinner plate.

Figure 8 shows a micrograph of atomic welds. Note the spots of burned metal and the extreme difference in grain size and formation. The bond between the weld metal and parent metal is also very poor.

Figure 9. S. N. Diagram of oxyacetylene welds compared with fire-box steel in endurance limit. The endurance limit of these four specimens varied from 10,000 lb. per sq. in. for the weakest to 17,000 lb. per sq. in. for the strongest.

Figure 10 shows the grain structure of oxyacetylene welds. The entire area of the crystal is not shown in the picture. In many cases the single crystals could be outlined on the polished surface with the naked eye. The wide difference in size of the grains in the welded area in comparison with the grains in the metal just adjacent to the weld is one of the primary causes for the failure of the oxyacetylene weld in fatigue tests. At the same time this grain size difference does not materially decrease the strength of the weld in tension and compression, as will be shown in a later figure.

Figure 11 compares metal arc welds with fire-box steel in endurance limit. This graph represents the increase in strength in this type of welds as far as endurance limit is concerned. The curves shown represent part of the tests which were made on this type of weld over a period of about five years prior to 1931.

Fig. 5 (Upper)

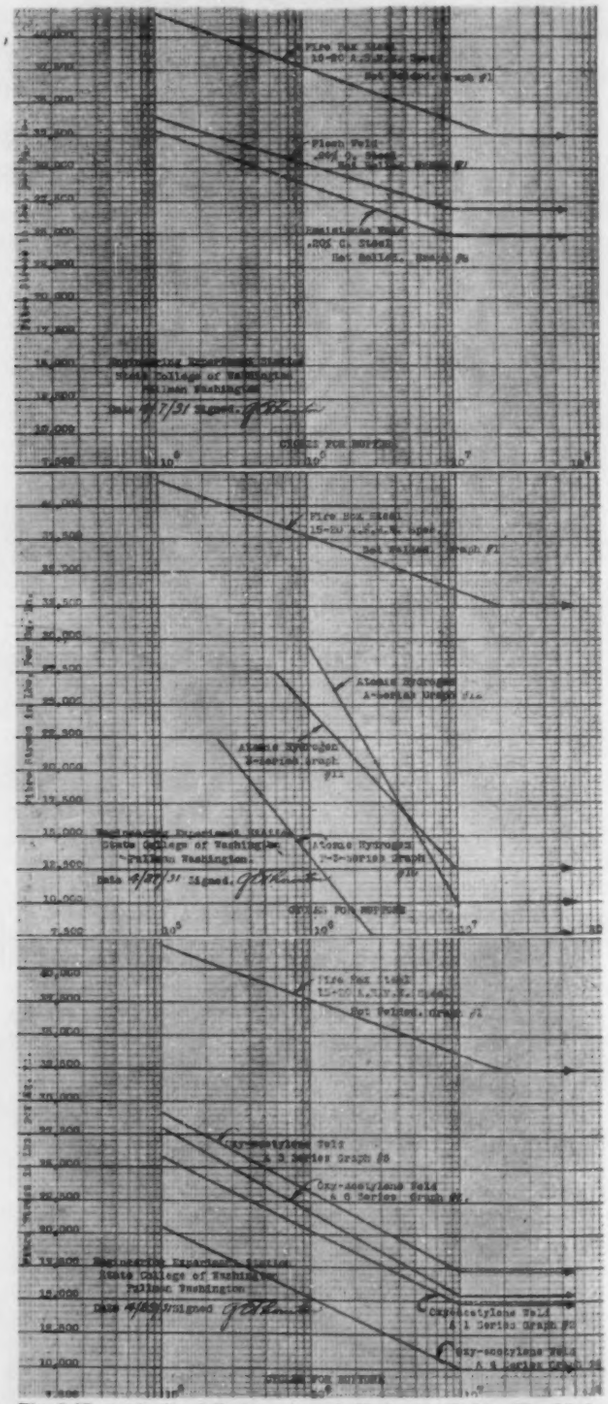


Fig. 7 (Center)—No. 3 Series. Atomic Hydrogen Weld. Was Made with ⅛-In. Chrome Vanadium Filler Rod Using 20 Amps. 50 Volts. Double V We'd

Series A. Single V Weld Made by Manufacturers

Series P-3-4. Double V Weld Made by Manufacturers

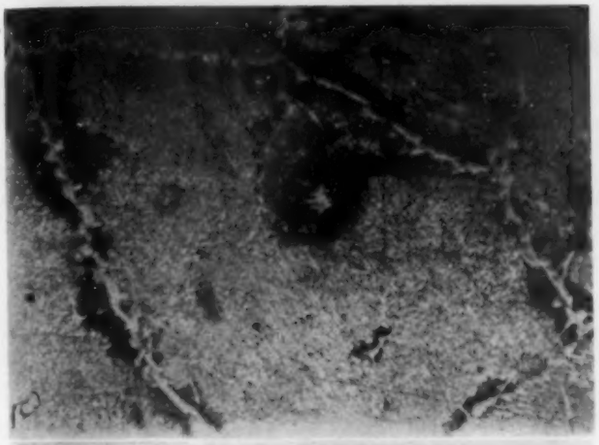
Fig. 9 (Lower)—A-1 Series. Oxyacetylene Weld Single V Low-Carbon Rod Oxygen to Acetylene 1.14

A-6 Series. Oxyacetylene Weld Double V Chrome Vanadium Rod. Ratio of Oxygen to Acetylene 1.08

A-4 Series Oxyacetylene Weld Double V Low-Carbon Rod. Ratio of Oxygen to Acetylene 1.04

A-3 Series. Single V Vanadium Welding Rod. Oxygen to Acetylene Ratio 1.00

Fig. 10—Shows the Extreme Size of Grains Which Predominate in Oxyacetylene Welding. This Large Grain Structure Is Also True for Atomic Hydrogen Welds



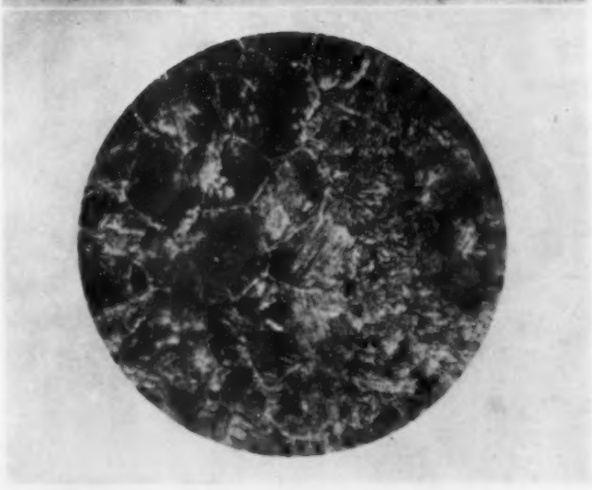


Fig. 12—A Micrograph of a Good Metal Arc Weld at 750 Diameters. Note the Absence of Pits, Oxides or Points of Poor Bond. This Picture Is Representative of the Welds as Made by Manufacturers of Class 1 Pressure Vessels

Figure 13 shows a series of typical welded coupons tested in tension. You will notice that the rupture in the specimen has not occurred in the middle of the specimen at which the welded area is located, but has occurred at one side of the weld. These specimens have been carefully machined to within 5 ten-thousandths of an inch. The welded area when compared in strength with the same cross-sectional area not welded has produced results much better than the metal not welded.

Figure 14 shows typical test specimens of welded metal which have been tested for endurance limit. The weld is in the exact center of the specimen and you will notice that all of these specimens except two have broken in this welded area. This is very typical of such specimens.

The figures give you a mental picture of why strenuous efforts were made by the welding industry to overcome the defects in these different types of welding.

After the report was made to the Fundamental Research Committee in Philadelphia, steps were taken by the welding companies to eliminate the defects in the weld metal and to increase the strength of this metal. This experimental work immediately brought out in the industry the use of covered electrodes, annealing of the weld, peening of the weld metal, use of different types and kinds of welding rod and many other things for the betterment of the weld.

Probably the most good has been accomplished by the use of the covered electrode and the shielded arc. Since this technique is applicable to a greater degree in the metal arc type of welding, we can expect to see more advance in this type of welding.

Locked-up stresses in metals which are welded and hardness differences between the metal in the weld and the parent metal in the original bar are other items which tend to affect the endurance limit of welded metals. In certain welded specimens which were tested, locked-up stresses in welded rails were encountered which were in excess of 35,000 lb. per sq. in. These stresses were measured by means of strain gages. Such stresses as these tend to make any data obtained from the tests very erratic and unreliable. When hi-carbon or hi-strength welding rod is used or when vanadium or

Table 1—Fatigue Test

Specimen No.	Stress	Cycles for Failure	Location of Break
A-3	10,000	Did not break	
A-12	10,000	Did not break	
A-20	12,500	9,770,000	Weld
A-20	12,500	5,560,000	Weld
A-2	15,000	9,400,000	Weld
A-4	15,000	9,660,000	Weld
A-15	15,000	5,340,000	Weld
A-19	17,500	4,180,000	Weld
A-17	17,500	6,900,000	Weld
A-21	17,500	2,840,000	Weld
A-29	20,000	3,340,000	Weld
A-8	20,000	10,500,000	Weld
A-11	20,000	1,180,000	Weld
A-14	22,500	1,960,000	Weld
A-25	22,500	1,290,000	Weld
A-10	22,500	2,910,000	Weld
A-7	25,000	991,000	Weld
A-9	25,000	2,320,000	Weld

Specimen No.	Ultimate Strength	Location of Failure
A-1	57,500	Parent metal
A-5	56,700	Parent metal
A-6	57,200	Parent metal
A-14	57,800	Parent metal
A-16	56,800	Parent metal
A-22	58,800	Parent metal
A-23	62,400	Weld
A-24	54,700	Weld
A-27	60,400	Parent metal
A-28	62,200	Parent metal

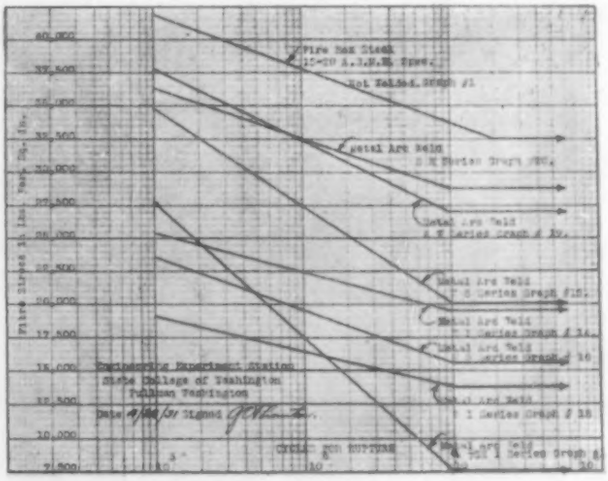


Fig. 11—W-1 Series. Metal Arc Single V 200 Amps. 1/8-In. Low-Carbon Rod
W-6 Series. Single V Medium Carbon Rod 20 Volts 130 Amps.
W-3 Series. 210 Amps. 5/32-In. Flux Covered Rod Single V
GE-1 Series. Metal Arc Double V 210 Amps. 5/32-In. Coated Rod
P-1 Series. 195 Amps. 20 Volts. Metal Arc Double V. Bare Wire.
AW-Series. Metal Arc Single V Covered Electrode
SR-Series. Metal Arc Single V Covered Electrode. Stress-Relieved

Fig. 13 (Upper Two Rows)

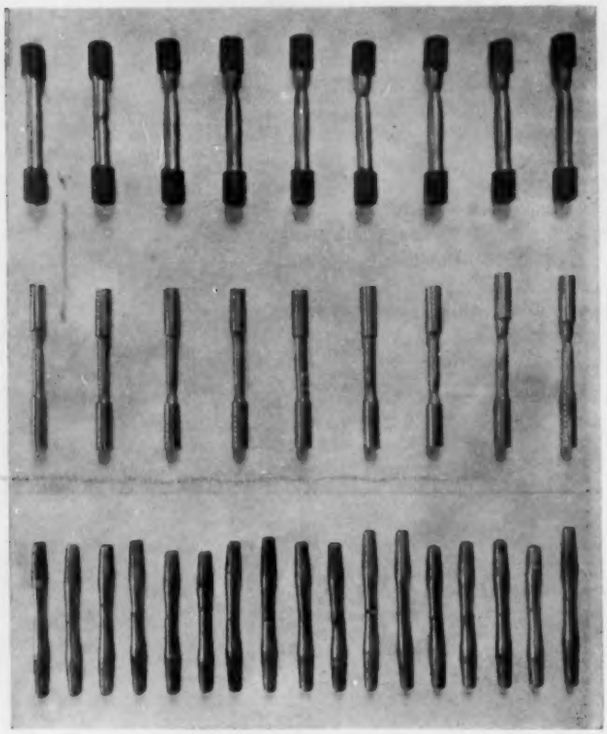


Fig. 14 (Lower Row)

chromium is used in the welding rod, there is, in certain cases, as high as 150 points difference in hardness on the Brinell Scale between the metal in the weld and the metal in the original plate.

If you examine the data in Table 1, taken from endurance limit or fatigue tests, you will see that to the uninitiated it might prove quite disturbing, and in fact it has proved so to individuals who were contemplating the use of welding in some of their manufacturing operations. Such data is bad psychology when taken from tests of inferior welds and is not so very reassuring when taken from tests of the best welds. You will note that these specimens when tested in tension as indicated by the lower set of figures run quite high for ultimate strength, and that nearly all of them have broken outside the welded area.

Table 2 is representative of test data of good welds and is taken from specimens furnished by a maker of Class I Pressure Vessels.

You will notice that all of the specimens which failed in fatigue have failed in the weld. Those specimens which were tested in tension as shown by the lower set of data have all ruptured outside the weld area.

This failure of the specimen in the weld is not an indication of the weakness of the weld but is an indica-

Table 2—Fatigue Test

Specimen No.	Stress	Cycles for Failure	Location of Break
SR-10	20,000	14,750,000	Did not break
SR-14	20,000	15,400,000	Did not break
SR-15	20,000	14,130,000	Did not break
SR-12	25,000	15,400,000	Did not break
SR-9	25,000	11,300,000	In weld
SR-13	25,000	9,500,000	Did not break
SR-7	27,500	12,370,000	Did not break
SR-1	27,500	710,000	In weld
SR-6	27,500	8,000,000	Did not break
SR-16	30,000	11,000,000	In weld
SR-2	30,000	1,400,000	In weld
SR-11	30,000	3,200,000	In weld
SR-8	32,500	1,700,000	In weld
SR-5	32,500	169,000	In weld
SR-3	32,500	1,250,000	In weld

Specimen	Ultimate Strength	Elongation	Failure
SR-1	57,600		In parent metal
SR-3	57,800		In parent metal
SR-4	59,800		In parent metal
SR-5	58,600	29.0%	In parent metal
SR-6	61,400	29.5%	In parent metal
Average	59,060	29.25%	

Fig. 15

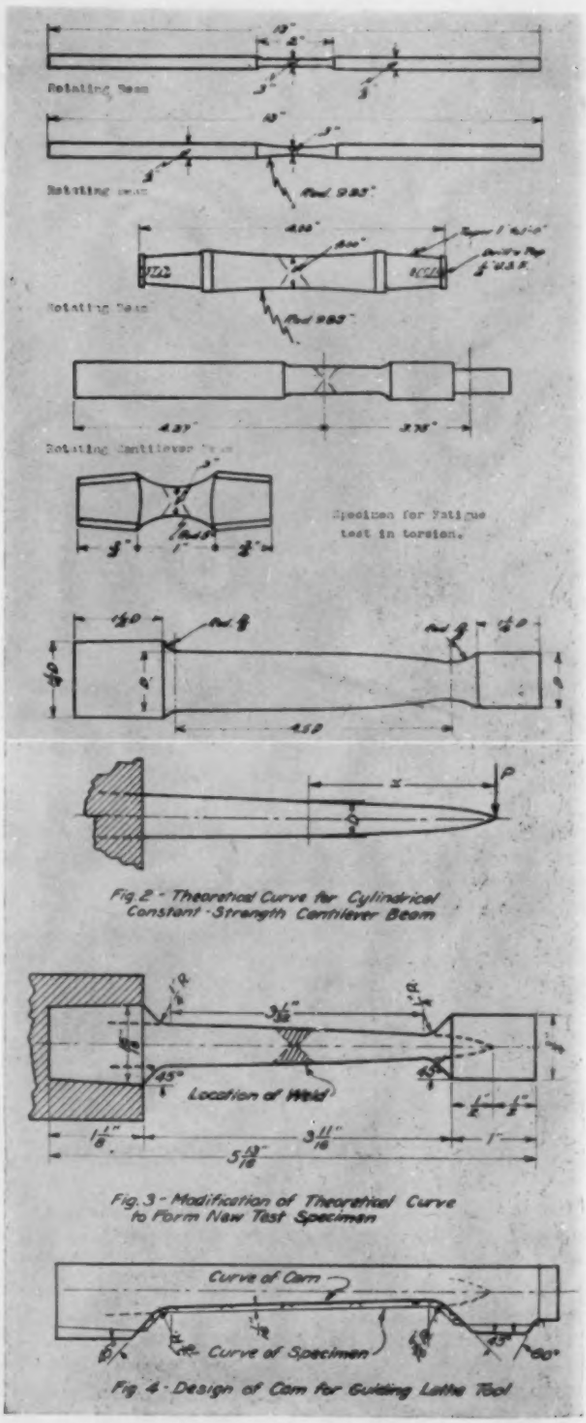

Specimen for Fatigue test in Torsion.
Fig. 2 - Theoretical Curve for Cylindrical Constant-Strength Cantilever Beam
Location of Weld
Fig. 3 - Modification of Theoretical Curve to Form New Test Specimen
Curve of Cam
Curve of Specimen
Fig. 4 - Design of Cam for Guiding Lathe Tool

Fig. 16

Fig. 18

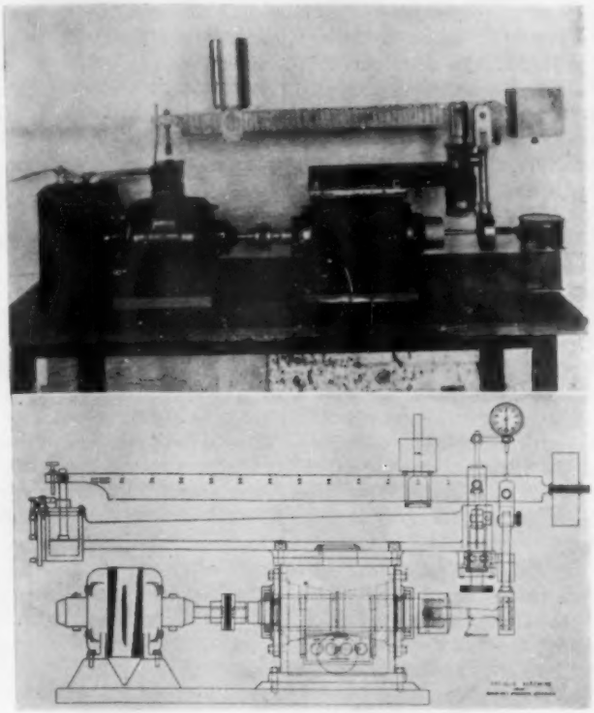


Fig. 17

tion of poor design in the specimen used. From an examination of several types of specimens used in the determination of endurance limit, you will notice from Fig. 15 that the specimens are designed to break at a central section. If the weld is located at this critical section we get data on the weld but we also create distrust in metals so welded. In order to eliminate this distrust a new type of machine was developed which would use a new type of specimen.

Figure 16 shows a constant strength, rotating cantilever beam-type specimen, which if stressed at the right-hand end will produce the same unit stress at any point in the specimen between the two fillets. If this were to represent a welded specimen the weld would have as fair a chance of withstanding rupture as any other part of the specimen. The specimen would break at the weakest point.

This type of specimen is not difficult to make and can be accurately machined on a machine lathe with compound cross head using a cam of correct outline in conjunction with a cam follower. This specimen has been recommended to the Standards Committee of the AMERICAN WELDING SOCIETY for adoption by the Society as a standard. As to its adoption in this exact form I cannot say, but it is a basis, at least, upon which to build. This type of specimen does have one defect, however, and that is from the point of shear. The shearing stresses involved by subjecting the outer end to a bending load are not too excessive, however. We are attempting, by means of a curve, to evaluate the load entirely as a bending load. This cannot be computed mathematically and must be determined empirically.

Figure 17 is a line drawing of a machine for using the rotating cantilever constant strength specimen. This machine has many advantages over the Farmer Type as far as placing the specimen, determining the stress, deflection, and so forth, is concerned. The load may be varied from a few hundred pounds to 75,000-lb. stress on the specimen by shifting the weights along the beam. The deflection is read directly to the nearest one-thousandth of an inch.

Figure 18 shows one of the machines in operation. Its operation is very quiet and there is little or no vibration, as indicated by the dollar standing on edge upon the weights as the left end of the balance beam. In the original drawing a dash-pot was provided at the end of the balance beam to prevent the beam from chattering at light loads. If the specimen were turned true, it was found that with the specimen in the machine and running with no load there was no vibration of the outer end of the beam. This dash-pot was eliminated from the machines which were already constructed. If the end of the beam vibrates it is an indication that the specimen is not true and, therefore, it is eliminated.

We are expecting to use machines of this type in carrying on our work in Fatigue, not only of welded metals but also of alloy steels.

All-Welded Steel Barges

By **R. B. REID**

✦Mr. Reid is connected with the News Bureau of the General Electric Company.

SIX of 27 all-welded steel barges for the transportation of bananas in shallow waters. The barges were constructed by the Equitable Equipment Company, Inc., New Orleans, for shipment to Central America. They have a length of 60 ft. and a width of 20 ft. and the hulls and decks are fabricated of 1/8-in. steel plates. The total depth of each barge is 3 ft. and each has a draft of 6 in.

Fig. 1—View of Barges for Bananas

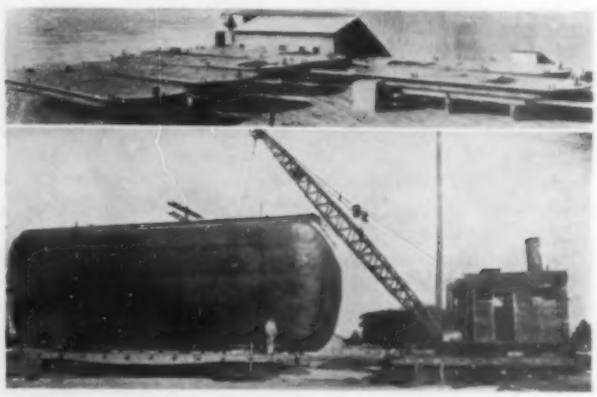


Fig. 2—View of Bottom of Barge Showing Details of Welding

Reconditioning Rail Ends

By J. C. HARTLEY

✦Presented at February 26th meeting of Philadelphia Section, A. W. S. by J. C. Hartley, Asst. Engr. Pennsylvania Railroad, Altoona, Pa.

THE successful development of any business enterprise requires certain factors or groups of factors upon which the foundation for the future structure is built, and the cost of whatever article or item of work it may be must be held as low as possible in comparison with the results desired to be obtained.

Railroad maintenance is divided into maintenance of equipment and maintenance of way. Maintenance of way is the actual maintaining or keeping in condition the physical property of the railroad, consisting of: ties, rails and appliances; tunnels and subways; underground tubes; bridges, trestles and culverts; elevated structures; roadway; ballast, crossings and signs; station and office buildings; roadway buildings; water and fuel stations; shops and enginehouses; grain elevators; storage warehouses; wharves and docks; coal and ore wharves; telegraph and telephone lines; signals and interlocking plants; power plants; dams; canals and pipe-lines; power plant buildings; substations; transmission and distributing systems; underground conduits and miscellaneous structures.

One of the most important items in the above list is that of the rail. Rail is the heavy-duty agent of the maintenance end of the railroad transportation structure, and upon it rolls the transportation wheel loads of as high as 40,000 lb. at a speed varying at least from five to eighty miles per hour. One can readily see that rail, therefore, plays an important part in railroad transportation, and therefore to avoid unnecessary and costly rail renewals, it is essential that rail service life should be closely analyzed and the most economic method used to prolong that life, in order to avoid heavy renewal charges.

The question of rail service life is, therefore, very important and various methods have been pursued to prolong, with safety, this life.

Not considering at this time sub-grade conditions, type of ballast used, section or weight of rail as contributory factors in the demolition of rail fiber and subsequent unfitness for further service, we will consider only the rail end wear, within the limits of the splice bar, which is caused in some instances by inequalities of rail height at joints, but the major portion of this wear is caused by the impact of wheel loads moving over two adjacent rail head surfaces where they are connected together by joint or splice bars. Some of this wear, or batter as we designate it, occurs on the leaving end of the rail, but the majority of the impact is absorbed by the receiving end of the receiving rail at the joint.

Rails are laid originally in track with the ends a standard distance apart, which distance varies according to the temperature of the steel at the time laid, and this opening between rail ends allows for expansion and contraction of the steel under varying temperatures.

Under traffic and temperature conditions these rails move longitudinally and the openings between rail ends change, some increasing and others diminishing, resulting in some openings being wide and others as tight almost as if welded together.

As the opening increases, the result of the impact is greater and causes a depression in the rail head of varying depth directly proportional to the number of impacts received; in other words, the greater the traffic and axle loads handled, the greater this depression or batter in the rail head surface will be.

When this batter reaches $^1/_{32}$ in., it is distinctly felt and heard by one riding over such a stretch of track, and to maintain such joints for smooth riding qualities requires an excessive amount of maintenance which means constant supervision and labor and excessive expenditures, in addition to quickly bringing such rail into a condition unfit for high-speed passenger and freight service, and therefore requiring complete replacement with the new rail. In order to secure further use of this battered end rail, it was used in sidings or yard tracks as its condition warranted, although at a heavy expenditure of labor and material in making this change—the labor alone amounting to $1212 per mile.

By this method a heavy tonnage of good rail, with the exception of the battered end, was lost for main line use. In order to salvage this heavy tonnage, lengthen its service life and secure the benefit of its hardened head surface, cold-rolled by traffic, battered rail was removed from track and 12 in. to 18 in. of rail sawed off each end; rails redrilled to fit standard bars; old bars were reformed; the cropped rail classified by height and wear and re-applied in main track at a considerable saving over the purchase and application of new rail, as well as securing lengthened service life, at an expense however of losing in miles of track the crops or sawed-off portions of battered rails ends, which in normal times represented a heavy loss in track miles of rail which by this process became scrap; and the mileage so lost had to be provided for by new rail.

Cost per Mile for Cropping Rail Method

Transportation both ways between track and cropping plant	$326.35
Handling rail both ways between track and cropping plant under traffic	816.00
Cropping 320 rails	80.00
Stripping and loading rail "work-wise" for safety in re-handling	12.00
Additional joints required due to cropping off ends	30.66
Additional bolts required	1.58
Additional nut locks required	0.38
Additional joint maintenance required per annum	27.93
Loss of cropped ends	120.00
Additional fit rail required per mile to fill out ends cropped	216.00
Total cost per mile for cropping, excluding new rail cost	$1630.90

The average life of P.S. 130-lb. rail in main tracks, heavy traffic territory, is estimated at 8.9 years and, if that service life can be increased without detriment to the rail fiber and also avoiding heavy labor expenditures, a real economical saving is obtained.

The Pennsylvania Railroad began building up rail ends of unequal height and where excessive batter existed by the oxyacetylene process in about 1918, but the work was performed only where such poor conditions existed, no attempt being made to bring to a smooth surface out-of-face stretches of track. After closely following the wearing qualities of such built-up rail

ends, the additional rail service life obtained and the saving of maintenance labor which resulted, it was decided to extend more fully this class of work and build up the joints in continuous stretches of track, so as to improve not only the general riding conditions but secure the advantage of the decreased maintenance cost and extended rail service life.

Three to five years additional service life were secured from rail ends built up by gas welding in proportion to the traffic density in the territory where the work was done, but the lower per joint cost obtained was $1.21 and the surface secured on the finished job was not what is desired for smooth riding and allowed rail end batter to build up more rapidly than if an even rail head surface is secured as the finished product of the welding operation, such as is obtained by the use of a reciprocating grinder.

After studying the operation with a view to lower production cost and a better finished product, we developed a two-flame welding torch, consisting of two No. 10 welding tips placed side by side, $^{7}/_{16}$ in. center to center, and so connected to a gas-distributing chamber that an equal flow of gas was obtained from each tip.

To obtain the proper flow of gas and not draw any acetone from the cylinder, it was found necessary to use two acetylene tanks connected by manifold to one of oxygen. With this set-up less pressure is used per tank of acetylene and we are able to secure more gas from the tanks.

The two-flame welding tip torch deposits the metal more quickly; therefore, considerably less heat is used in building up rail ends at joints. No hot cutter is used to secure the opening between rail ends, this work being done by a joint cross grinder using a $^{1}/_{8}$ in. bakelite grinding wheel which does not injure or disturb the welded metal and gives a square finish to the rail end.

The welded surface is then brought to a true surface with a reciprocating grinder. The result obtained is all that is desired for good riding and retards rail end batter as the causes for this batter have been mostly eliminated.

The metal deposited in the welding operation plays an important part in the result obtained, as this metal, when deposited, should be as near the chemical analysis of the parent metal as possible, but also should be harder than the metal adjacent to the weld, so as to be able to withstand the impact of moving wheel loads over the joint and retard rail end batter.

After experimenting with different types of welding wire, we have adopted the following rod:

Chemical Analysis

Carbon	0.95 to 1.10%
Manganese	0.45 to 0.65%
Phosphorus	0.03% maximum
Sulphur	0.03% maximum
Silicon	0.20% maximum

This rod is furnished unannealed, lime coated, mill finish.

The wire is furnished in what is called ribbon forms, being $^{1}/_{8}$ in. thick by either $^{1}/_{2}$ in. or $^{3}/_{4}$ in. wide by 36 in. long, the greater width being used for heavy welds.

By the use of this two-flame tip and wire, and not taking into consideration the grinding of the joint, as this feature is not included in the previous per joint cost, the production per man has been increased 60% and the per joint cost has been decreased 48% or to $250 per mile—a saving over cropping of rail ends of $1381 per mile.

We have built up 1344 miles of rail or 672 miles of track by the oxyacetylene welding method and with the anticipated further reductions in cost and further increased production we will be able to use this method more extensively, resulting in a still further saving in maintenance of way costs.

To those who are interested in the method of procedure which we use in the building up of battered rail ends, our general instructions governing this work are as follows:

Rail to be welded must be clean, free from dust, dirt, grease, paint or other foreign substance. Where laminations, oxidized metal or cracks exist under the rail head surface, which cannot be thoroughly removed by the use of the wire brush or chisel, the bad material must be washed out with the torch before additional metal is applied.

All chipped or spalled rail ends will be cut or washed down to clean parent metal, welded and brought to a true surface.

Rail ends which are cupped and the surface upset will have the cupped surface built and the upset portion brought to a true surface.

When rail ends are not battered, but when measured show a difference in height, the low rail will be built up to the height of the high rail with the proper run-off, or the high rail ground down to the proper surface with the low rail, if more conomical.

All rail ends over-run by traffic and welded metal over-run will be ground off flush with the original rail end, and when rail ends are tight they will also be cross cut by a $^{1}/_{8}$ in. width cutting wheel to a depth of $^{3}/_{16}$ in.

In depositing metal on the rail head, start must be made at the end of the rail and work toward the end of the portion to be welded until the portion of the rail head to be welded is completed.

No welding is to be done on the rail except within the limits of the splice bars and not farther than 10 in. from the end of the rail.

Under no conditions shall any building up, reforming or heat be applied outside of these limits.

Track Conditions to Be Taken Care of before Any Welding Is Done

Joints must be thoroughly tamped and brought to a true surface. Bars must fit snugly throughout, particularly at the center of the top of the bar, with sufficient drawing space between inside of bar and web of rail. If inside of bar engages web of rail, is too close to allow proper drawing space or does not have a close fit at the center of the top of the bar, bars must be renewed with reformed over-sized bars.

Bolts must be tightened and, if necessary to secure proper tightness, must be renewed.

The proper expansion of rails at joints must be provided for and maintained to avoid chipping of rail ends when tight under traffic.

Joint ties, when necessary to provide proper joint support, must be renewed.

Ballast at joints must be clean to provide proper drainage.

Limits of Batter

All rail ends having any batter up to $^{1}/_{8}$ in. will be welded.

Rails with ends battered in excess of $^{1}/_{8}$ in. or distorted by line or surface kinks, or with general corrugated surface, will not be welded.

Measuring Rail End Batter

Place a 24-in. straightedge, edge along the center line of the rail head, with the center of the straightedge midway between the rail ends, at the center of the joint. Where the edge of the straightedge rests on the rail head either side of the rail ends are the approximate limits of the weld to be made.

To check the weld to be made on each rail end, place the 24-in. straightedge, edge along the center of the rail head, one end even with the edge of rail to be measured. The limit of weld will be from the point where the top of the rail head is in contact with the lower edge of the straightedge, so applied, farthest from the rail end. Where the rail end metal is upset adjacent to the battered area, the weld should end at the upset portion, nearest the rail end and the upset portion heated and flattened to a true surface.

The first method mentioned gives you the general condition at the joint, but the latter method should be strictly followed to determine the exact limits of the weld.

Where difference in height at the rail ends occurs, the work to be done can be ascertained by sliding the 24-in. straightedge along the rail, keeping it in contact with the center of the rail head, over the adjacent rail head, until it comes in contact with the rail head surface, which point will be the limit of the weld to be made.

Patrons today patronize the railroad which provides the best service. Such service consists of safety and speed of delivery, whether it be passenger or freight movement. The road-bed and particularly the rails must be maintained for this speed and the most important part of the rail assembly is the joint.

A perfect surface joint is an essential factor in contributing to and maintaining this speed, and the building up of battered or unequal height rail ends at joints not only provides a smooth-riding joint but also lessens the annual maintenance of each joint so treated.

In order to provide a perfect surface joint, we intend to surface grind each built-up joint with a special grinder developed for this purpose, as our experience indicates that all welded rail ends should be ground to a smooth surface, in order to remove all irregularities which contribute to rail end batter. It is a portable, reciprocal grinder manipulated by one man, although an additional man or more may be required for this operation, according to the density of traffic conditions encountered.

With the perfect surface thus secured, the visual effect of wheel load impact is retarded under fairly heavy traffic for about three years, thus extending the rail service life by that amount, and the same rails can be rewelded when sufficient service batter re-appears to warrant it; thus further increasing the service life and effecting a monetary saving over the cropping method of $1631, less $250 (cost of gas welding per mile of track) or $1381 per mile for each welding operation as required, which does not include joint maintenance cost.

Gas welding is also performed on open-hearth frogs in yards where speed is not a factor, effecting still further savings in maintenance of way costs.

We also have under traffic test, new rails with about $2^1/_2$ in. of the rail ends heat treated by the oxyacetylene method. These rails, so treated, at present seem to indicate that their service will be considerably increased, due to the hardened rail end resisting the wheel load impacts, but we are not prepared at this time to furnish any positive figures as to the possible rail service life to be obtained from this method.

Welding Aluminum with the Gas Torch and the Metallic Arc

By G. O. HOGLUND

✦Paper presented at November 22, 1933, meeting of New York Section, A. W. S., by G. O. Hoglund of the Aluminum Company of America.

FOR twenty or more years the welding of the aluminum alloys with the gas torch has provided a useful tool for joining these materials, both in this country and abroad. The past decade has broadened the fields of application of these alloys tremendously with consequent development and progress in the process of fusion welding. The following material is presented to provide information on the processes as they are applied today with some data that may prove useful in estimating welding costs for practical shop operations.

The production of aluminum torch-welded parts is done commercially with either the oxy-hydrogen, oxy-acetylene or oxy-natural gas flame. From the standpoint of strength or soundness of the welds there is little to choose between the three gases. From the standpoint of cost, local conditions in the plant determine the correct choice. However, on the heavier gages, 0.250 in. and above, oxyacetylene is almost universally applied, as the higher flame temperature and the flame speed permit faster welding. On light-gage material, 0.050 in. and under, particularly the cooking utensil field, oxy-hydrogen and oxy-natural gas find extensive applications. The advantage of using the latter two gases is particularly apparent when these gages are welded by persons inexperienced on welding aluminum.

All of the aluminum alloys are covered with a protective oxide coating. This coating is beneficial and contributes to the excellent resistance of these alloys to corrosive attack, but it must be removed when welding as it will prevent the ready flow of the molten metal under the flame into a sound weld. This is done most readily with a flux that will break up and flow the coating away from the weld. There are a number of suitable fluxes on the market. The actual fluxing operations are usually handled by mixing the powdered commercial forms of this material with water to the consistency of a watery paste in a glass or an aluminum receptacle. The mixture is then painted on the joint or applied to the welding rod by dipping. For localities where the tap water carries more than the average quantities of impurities, the use of distilled water for mixing the flux is recommended.

For joints requiring the application of a filler rod, two compositions are used for practically all applications. For welding commercially pure aluminum (2S) and for welding the aluminum alloy 3S, a 2S welding rod is recommended. For welding the other alloys, practically all of which contain larger quantities of alloying constituents, the use of a silicon-aluminum welding rod is recommended. This rod, commonly known as 43S alloy, has a comparatively low melting point and contributes

considerably to eliminating cracks in the welds or the parent metal near the weld when the parts cool. This is particularly true when welding the heat-treatable alloys in jigs and fixtures where there may be a tendency to prevent the uniform contraction of the parts after welding.

The conventional methods of preparing sheet or plate are used when welding in the aluminum alloys. Butt welds in sheet or shapes up to No. 14 B & S gage (0.064 in.) can be welded with no preliminary preparation in the way of veeing or notching. The buckling of light-gage parts containing large flat areas with welded joints is frequently minimized by running a 1/4-in. radius bead about 1 in. on each side of and parallel to the weld. On material from 0.064 in. to 1/8 in. thick, good penetration and increased welding speed are obtained by notching the joint with a cold chisel. The notches are cut about 1/16 in. deep and spaced approximately 1/8 in. apart along both abutting edges of the sheet. It is an almost universal practice to vee joints where the gage is heavier than 1/8 in. This is generally done by a machining or a pneumatic chisel operation. A vee with an included angle of from 70 deg. to 90 deg. is cut leaving a lip about 1/16 in. wide on the lower side. Sheet 1/2 in. or over is veed and welded from both sides.

Estimating the cost of aluminum welding jobs is of interest in view of the greater frequency with which these jobs are occurring. Table 1 contains a résumé of data collected in a plant doing general jobbing work and represents actual production conditions rather than results from laboratory tests. Under ideal conditions there is no question but that the rates given can be increased considerably.

The data in Table 1 are given in the form of the amount of welding one man can do per hour in order to make the data applicable generally. Rates for welders differ in different localities and it should be comparatively easy to estimate the cost of a welding job, once it is determined how long it will take to do the job. The data are entirely for gas welding.

Some additional factors affecting the cost of welding are itemized below:

1. Gas Used.—When welding with the oxy-hydrogen flame, an experienced welder will usually use about two bottles of oxygen and five bottles of hydrogen in an eight-hour day. In welding with oxyacetylene, he will use about one bottle of acetylene to two bottles of oxygen in an eight-hour day. Both of these statements assume that the welder works consistently for the entire day, with no time out for the preparing of joints, setting up the work in jigs, etc.

2. Experience.—The amount of welding turned out is dependent to a certain extent on the individual doing the work. The figures given assume that the man not only is experienced in welding aluminum but also experienced in the particular type of work which is being considered; that is, an average welder will produce the number of feet of seam tabulated, after he has had an opportunity to become familiar with the type of work being done. For the first application of welding attempted by any company, an extra allowance of 25 per cent of welding costs would not be excessive, even though the welder has some experience in welding aluminum. For organizations where no welding of aluminum has been done, this should be increased, depending on the complication of the job in question.

3. Preparation of Joints and Tacking.—Table 1 does not consider the time necessary to vee and notch the joints and to tack the weld before the final welding. Shop practice varies a great deal in doing this work and it is not practical to give any figures which might be generally applicable. The tacking operations ordinarily are done at about three times the rate of straight welding along the seams, but a great deal depends on the time necessary to line up the work and get the parts placed right, which are a function of the particular job at hand. This does not lend itself to figures which can be generally applied.

4. Mitre Joints.—It is not possible to give definite figures for mitre joints, as the time of welding is generally not a function of the number of feet to be welded, but is dependent on the complication of the section being welded. The general statement can be made, however, that the joint can be welded in equal or less time than is required for welding a comparable joint in steel, and also in slightly less time than the joint would require if brass or bronze were used.

5. General Construction Welding.—Here again figures in the table should not be applied literally as it will generally require substantially more time than is shown above. The actual rate of welding on aluminum as compared with steel, however, is somewhat faster, and a reasonable estimate can usually be arrived at if the time necessary to weld the joint on steel parts is taken as a basis. This can be done in most cases, due to the more comprehensive data on welding steel which are available to most concerns.

An item which is frequently neglected, in computing costs when welding aluminum, is cleaning the joints after welding; consequently the cleaning operations are sometimes omitted. The flux must be removed after the joint is welded to prevent corrosive attack. One of the best ways known of doing this is immersing the parts for one hour in a 10 per cent sulphuric acid solution and washing the acid off the parts with running water. This item should be given consideration on every welding job, and if thoroughly understood will anticipate and and prevent field troubles. On very large parts, an immersion in acid may not be practicable. In this case a thorough washing with a brush and hot water or steam jet will clean the joint.

Table 1—Data on Torch Welding Aluminum Sheet

Gage, In.	Preparation of Joint	No. of Times Weld Gone Over	Gas Used	Tip Size, No.	Number Men	Wire Diam., In.	For 100-Ft. Wire, Lb.	Weld Flux, Lb.	Rate of Welding, Ft. One Hour
1/16	None	Once	Oxy-Hyd.	4	1	0.125	3.0	2	14.0
1/8	Notched	Once	Oxy-Hyd.	4	1	0.146	6.5	2	12.0
1/4	V one side and notched	Twice	Oxyacety.	5	1	0.184	20.0	4	10.0
3/8	V one side and notched	Twice	Oxyacety.	7	1	0.184	30.0	4	7.0
1/2	V both sides and notched	Twice outside, once inside	Oxyacety.	8	Welder and helper	0.250	35.0	5	4.0
3/4	V both sides and notched	Twice outside, once inside	Oxyacety.	8	Welder and helper	0.312	40.0	5	3.5

A joint that is cleaned can be tested for the presence of flux by dropping on it a few drops of a 2 per cent silver nitrate solution. If the joint is clean, there will be no precipitate formed and the solution will remain colorless.

Arc Welding

The use of the electric arc for welding the aluminum alloys is one of the rapidly expanding means of joining these materials. For manual welding, the metallic arc method has been proved successful by a considerable number of commercial applications. For automatic welding, the carbon arc offers promise and steps are now being taken to place a production unit in operation. At the present time, however, the metallic arc is established in the field and the following remarks apply only to that process.

Metallic arc welds in aluminum have the advantage that the area near the welds affected by the welding heat is considerably narrower than is encountered when using the gas torch. This is particularly apparent when welding the heat-treatable alloys. In addition, the tendency of these alloys to show heat cracks (caused by hot-shortness when torch welding), is minimized or entirely eliminated. The operation is faster than torch welding. The cost of metallic arc-welding operations is approximately the same as the cost of torch-welding operations, though a saving is generally shown on gages between 1/8 and 1/4 in., as no preliminary veeing or notching is necessary.

No special equipment is necessary to apply arc welding to aluminum, the standard motor generator sets found in most plants being satisfactory. On light gages (0.064 in. to 0.125 in.) it may be desirable on some equipment to include a resistance of 1/4 to 1/2 ohm, in series with the arc, to provide arc stability. A.C. welding equipment, particularly the type with a superimposed high-frequency current on the welding circuit, has also been used with excellent results.

A flux-coated rod is required for metallic arc welding. There are a number of suitable coated rods available. The flux coating serves the same purpose as in torch welding in removing the oxide surface film that would prevent the formation of a sound weld and, in addition, stabilizes the arc. Considerable testing and experience has shown that the most useful rod composition is an alloy of aluminum and silicon, and all of the standard rod is of this composition. For special cases it is frequently possible to prepare specially dipped rods with a rod composition the same as the parent metal.

Table 2—Electrode Size and Machine Setting for Metallic Arc Welding Aluminum

Thickness, In.	Electrode Diameter, In.	Amperes
0.064	1/8	45–55
0.081	1/8	55–65
0.102	1/8	65–75
0.125	1/8	75–85
5/32	1/8 or 5/32	85–100
3/16	5/32	100–125
1/4	5/32 or 3/16	125–175
5/16	3/16	175–225
3/8	1/4	225–300

The technique for metallic arc welding aluminum is comparatively simple and readily learned. The rod is mounted in the holder and the arc established by brushing against the work. A comparatively long arc is held until the edges start to melt and then shortened as much as possible. The motion along the seam on butt joints should be a straight forward or backward motion, the rod held vertically with no weaving. Recommended rod diameters and current settings for the first trial for any job are shown in Table 2. It is generally safe to choose a rod diameter the same as, or close to, the gage of metal being welded.

The arc welding of material below 14 B & S gage (0.064 in.) is somewhat difficult and is not generally attempted in production. From this gage up to 1/4 in., however, butt welds are made with no preliminary veeing or notching. Back-up plates of steel or copper are generally applied under the joint to insure adequate and uniform penetration. Material heavier than 1/4 in. is veed with a 70-deg. to 90-deg. vee, leaving a 3/16-in. or 1/8-in. lip at the apex of the vee.

The previous remarks made on removing torch-welding flux apply as well to arc welds. The flux on the joint after welding must be removed to prevent the possibility of corrosion troubles in service.

Discussion of Paper on "Electric Arc Welding under Water"

By JAMES R. WITHROW

†The paper on "Electric Arc Welding under Water" was presented by N. S. Hibshman and C. D. Jensen, with Metallurgical study by W. E. Harvey, at the Fall Meeting, A. W. S., Detroit, Oct. 2 to 6, 1933, and was published in the October issue of the Journal of the A. W. S. James R. Withrow is Professor of Chemical Engineering, Ohio State University, and Consulting Engineer.

THE whole question of lowered ductility is not necessarily a simple one. The presence of nitrides which settles the question for some is not believed to be a potent factor by others. The point raised seems natural that under water nitrogen would be largely excluded and should be expected to at least so reduce nitride occurrence that it should disappear as a factor. Yet the ductility actually was depressed. The response that "one-sided" welding was responsible for lowered ductility may close the question. Against this I will not suggest a doubt. It is a question of fact which can be determined by proper investigation, as can the presence of nitrides themselves.

However, if the suggestion that nitrides are significant at times is correct and the explanation of the depressed ductility given by Jensen (one-sided welding) be not entirely or always true, then the comparative absence of nitrogen from water becomes important. Welding under water certainly appears to effectively exclude atmospheric air access to the welding operation.

The suggestion in the discussion that oxygen was the cause of the depressed ductility seems doubtful, though by no means impossible. Into this question I do not choose to go. I do wish to call attention to the fact that water does not *completely* exclude nitrogen though it largely blankets it out.

The blanketing by water may be thought of as the equivalent of a "fluxing" or "slagging" protection of the metal. It does keep off great volumes of atmospheric

air ordinarily present during welding. However, we should not drive too rapidly to the conclusion that this necessarily eliminated nitrogen and enthrones oxygen as the active agent in depressing ductility or other possible nitrogen effects.

In an ordinary welding operation, atmospheric air flows in endless volume to and away from the welding work. In other words, the weld is always made in a bath of atmospheric air (like Jensen's work in a bath of water).[1]

As the air is heated or even destroyed (as nitrides or oxides are formed) fresh supplies of air or particles (molecules) of nitrogen and oxygen rush in endless stream toward and brush vigorously over the welding operation. This gives opportunity for intense chemical activity whose effects are always open to discussion.

Under-water welding would seem a very practical way to certainly eliminate this atmospheric air situation. For a little let us forget the water itself and the new set of chemical possibilities which it forces upon us.

Ordinary water is never entirely free from air (nitrogen and oxygen). The amount is greatly reduced compared with atmospheric air conditions. In fact, it is reduced to 2% as compared with 100% when welding in air. The other 98% is water when welding under water except in special cases.

Always either in air or under water, there is much more nitrogen than there is oxygen in either the atmospheric air or dissolved air.

In ordinary air there are 78 parts of nitrogen to each 21 parts of oxygen or 3.7 of nitrogen for one of oxygen. In water the nitrogen is 65 to 35 of oxygen or still 1.86 times the amount of oxygen.

It would seem that by under-water welding we have not entirely eliminated friend (or enemy) nitrogen. However, it is common chemical experience that the pressure toward a given result or effect depends upon how much of nitrogen, for instance, is present to press for attention, at any one time. Obviously, two per cent of nitrogen (in water) will be less powerfully insistant for its effect than would that in 100% atmospheric air.

However, in spite of all these so-called equilibrium effects, tending to reduce to a minimum the activity of nitrogen we must not forget that, after all, the amount of nitride ever formed is very low (a little seems to go a long way—how long?). This means that but an infinitesimal amount of the nitrogen circulating past an atmospheric weld is ever active in formation of nitrides. This suggests two possibilities to the chemical engineer, one that the great excess of nitrogen is necessary to get even a little effect (i.e., gaseous equilibrium laws hold) and, therefore, anything which reduces nitrogen's presence (flux, slag, water, other gases) will destroy its effects. The other possibility is that nitrogen has only occasional opportunities to assert its personality, perhaps due only to the presence of friendly helpers (catalysts). In this case even a small amount at such times will be effective. This is a question of fact which must not be overlooked in such chemical speculation. In this case covering by water, flux or other gases may not be impervious enough to prevent nitrogen activity when its gang is present (catalysts).

Another way of saying all this would be that in air we have roughly four volumes of nitrogen to one volume of oxygen. If these gases can both stick to the iron mixture then nitrogen hits 300% oftener than does oxygen. If oxygen only does the damage then while nitrogen is hitting a spot oxygen cannot, and so we have a nitrogen blanket through holes in which oxygen strikes its mark. Atmospheres of nitrogen or of oxygen, then, should give quite different results from atmospheric air (except nitrogen is really the effective damaging agent). In this latter case (nitrogen effective) with air we have a blanket of oxygen which is $^4/_5$ holes permitting strikes by nitrogen molecules—a $^1/_5$ protection, not very effective.

In case of under-water welding, therefore, if we ignore the dissolved nitrogen-oxygen situation in water, we have not necessarily eliminated nitrogen and fixed the blame upon oxygen. Nitrogen is still present.

Presumably it was understood that water would dissociate (1000° C. up) to an extent. This would give oxygen and twice as much hydrogen as oxygen. Again we have a blanket.

Not only this, but hydrogen is known to have an embrittling action under some conditions, a possible factor which cannot be overlooked.

Some factors would seem to be reasonably certain to be practically effective, giving great advantages to under-water welding:

1. The low solubility of air in water.
2. The temperature effect of the weld operation which tends to drive air completely out of the solution, producing a hot zone around the weld which would strongly repel dissolved air and might eliminate it entirely.
3. The blanket of steam and the blanket of dissociated steam-hydrogen and oxygen.
4. Finally the increased tendency to produce oxide with minimum of nitrogen present.

In other words, under-water welding gives a new welding condition as though we were welding in a stream of steam.

Without thought of criticism it should not be overlooked that if anyone conducted an experiment in a tank he would very quickly eliminate dissolved air by the heat effect, whereas, in any practical case of welding fresh water containing its quota of air would always be in circulation to the welding operation. Under-water welding investigations must always be done in a stream of water saturated with air.

Regarding the fundamental questions on general welding it seems as though experimental work could be done in a vacuum to answer some of these questions. In fact, nitrogen could be deliberately added to a torch to see if we could imitate the conditions which do seem to give nitrides.

Without intending any disrespect it would seem as though those interested financially in the development of gas welding have long been asleep in pushing sufficiently their apparent advantages in the gas torch, from the point of view of furnishing a blanket, by delivering inert gas under high pressure at the point of chemical activity, namely, the fused weld, thus keeping nitrogen and perhaps oxygen at a distance. This, of course, opens another kind of argument. I realize that much thought has been given to the matter but work done does not appear to be tremendously conclusive.

Some interested chemical engineering or metallurgical research worker should get us the facts.

In spite of the interesting apparent advantages of under-water welding, we did come out with a lower ductility, in which we appear to have a reasonable explanation in one-sided welding, upon which proof must still be furnished.

In any event this does not eliminate the necessity for getting precise information as to the scientific facts from the gas point of view.

Engineering never can have too many facts available.

[1] For the purpose of making clear and simple what might seem to be difficult chemical considerations, it is chosen to omit common *assumptions* as to the presence of gas ionization. Such considerations may be erroneous or not but in any event function merely to give but a new name or emphasis (mechanization) to the chemical speculations under discussion.

These should be interesting to both the electrical as well as the gas-welding industry.

By GILBERT E. DOAN

✦Paper on "Electric Arc Welding under Water" was presented by Messrs. N. S. Hibshman, C. D. Jensen and W. E. Harvey of Lehigh University, at the Fall Meeting, A. W. S., Detroit, Oct. 2 to 6, 1933, and was published in the October issue of the Journal of the A. W. S. Prof. Doan is with Lehigh University.

ASIDE from the importance of welding under water as an engineering accomplishment, it seems significant metallurgically in showing that welds made in the absence of atmospheric nitrogen have properties not superior to those made in the air, which is 79 per cent nitrogen by volume. Apparently it is not nitrogen which is solely responsible for the low ductility of bare-wire welds made in air. It may be oxygen altogether and not nitrogen at all, as is supposed by Messrs. Hensel, Hodge and other investigators.

Both nitrogen and oxygen are dissolved in water at room temperature and atmospheric pressure; moderate heating of the water, as in boiling, drives out almost all of the dissolved nitrogen and oxygen. The temperature of the water about the arc is certainly quite high and the "bubble" of steam (and probably of hydrogen and oxygen from dissociated water vapor) about the arc probably contains very little nitrogen, and hence one would expect the weld metal to contain very little if any more nitrogen than the original wire. Nevertheless, the elongation in the bend test of this under-water weld metal is not higher, but, in fact, is somewhat lower in the tensile test than that of the metal deposited in air, assuming, of course, that the test results submitted represent the properties of the metal and are not due to flaws in the specimens. There probably is plenty of oxygen present at the arc in under-water welding and, depending upon the equilibrium constant of the reactions

$$Fe + O = FeO \text{ and } H_2 + O = H_2O,$$

a considerable amount of oxygen may combine with the iron and enter the weld, resulting in the lowering of its ductility. The indications are that oxygen alone may cause welds to be low in ductility.

CURRENT WELDING LITERATURE

Barrels. Steel Supersedes Wood in Construction of Barrels for Beer. Iron Age (Dec. 28, 1933), vol. 132, no. 26, pp. 22–24.

Bridges, Plate Girder. Largest Electrically Welded Bridge in World. Indian Eng. (Dec. 15, 1933), vol. 94, no. 25, pp. 500–502 and 504–505.

Chemical Equipment. Electric Arc Welding in Chemical Industry. Chem. Age (Jan. 27, 1934), vol. 30. no. 761, pp. 77–78. Manufacture of vessels in stainless steel and monel metal.

Diesel Engines. Welded Steel Diesel Structures, E. Chapman. Welding J. (Dec. 1933), vol. 30, no. 363, pp. 369–372.

Diesel Engine Maintenance and Repair. Repairs to Oil Engine Parts by Welding. Welding J. (Dec. 1933), vol. 30, no. 363, pp. 358–360.

Iron Castings. Welding in Repair Work, C. W. Brett. Elecn. (Dec. 22, 1933), vol. 111, no. 2899, pp. 773–774. Rapid development of process for welding cast-iron at temperatures very much lower than those previously applied.

Machine Shops. Design, Fabrication and Erection of Small, All-Welded Machine Shop, C. Helsby. Structural Engr., New Series (Jan. 1934), vol. 12, no. 1, pp. 2–9. Methods employed in erecting shop at Harmondsworth; Preparation of joint construction.

Motor Truck Manufacture. Using Welding Torch to Fill Special Needs Helps Reduce Truck Operating Costs, B. Burgan. Commercial Car J. (Dec. 1933), vol. 46, no. 4, pp. 30–31. How welding torch can be used in making of new things, designed to make work easier and truck ownership less costly.

Nickel Alloys. Jigs for Welding High-Nickel Alloys, F. G. Flocke, J. G. Schoener and R. J. McKay. Sheet Metal Industries (Oct. 1933), vol. 7, no. 78, pp. 379–380.

Oxyacetylene Welding. Report of Oxy-Acetylene Committee, International Acetylene Assn., Philadelphia, Pa., Nov. 1932, 77 pp., illus., diagrs., charts, tables. Chart showing scope of oxy-acetylene processes; abstracts of specifications of materials which may be welded; interpretation of certain well-known welding codes; information on testing of welded objects.

Oxyacetylene Welding. Pressure Booster Installations for Acetylene Distribution for Welding, C. S. Milne. Welding J. (Dec. 1933), vol. 30, no. 362, pp. 365–368.

Pipe Lines. Navy Boiler Drum Practice Used for Fusion Welded Pipe. Boiler Maker & Plate Fabricator (Formerly Boiler Maker) (Jan. 1934), vol. 34, no. 1, pp. 2–5.

Planning for Production by Welding, G. M. Buchanan. Sheet Metal Industries (Dec. 1933), vol. 7, no. 80, pp. 498–500.

Poles, Steel. Reclaiming Steel Poles by Welding, J. Ross. Elec. Traction & Bus J. (Dec. 1933), vol. 29, no. 12, p. 383.

Qualifying Tests for Welders, E. Lunn. Boiler Maker & Plate Fabricator (Formerly Boiler Maker) (Jan. 1934), vol. 34, no. 1, pp. 18–20.

Sheet Iron, Welding of. H. Melhardt. Sheet Metal Industries (Jan. 1934), vol. 8, no. 81, pp. 47–49.

Steam Pipe Lines. Welding Steam Transmission Lines, F. E. Kise. Heating, Piping and Air Conditioning (Jan. 1934), vol. 41, no. 1, pp. 14–16.

Structural Steel. Welded Steel Construction, L. Jones. Iron & Steel Engr. (Dec. 1933), vol. 10, no. 12, pp. 369–370.

Tugboats. Two Diesel Powered Electric Welded Tugboats. Motorship (Jan. 1934), vol. 19, no. 1, pp. 13 and 15. Texaco 325 and Caillou, built by Pennsylvania Shipyards, Beaumont, Tex.; length oa 70 ft.; beam 18 ft.; depth 7 ft. 6 in.; propelled by 6-cyl., 4-cycle, airless-injection Winton-Diesel engine with 10-in. bore and 14-in. stroke developing 250 hp. at 375 rpm.

Valves and Valve Gears. Stelliting Valve Steels, F. R. Banks. Mech. World (Jan. 26, 1934), vol. 95, no. 2456, pp. 71–72.

BOOKS

"Industrial Radiography," by Ancel St. John and Herbert R. Isenburger. This book represents the practical aspects of industrial radiography in a form and language which can be understood by those who desire a thorough understanding of the basic theories involved. Chapters include: Introduction; The Infancy of Radiography; The Early Years of Radiography; The Present Status of Industrial Radiography; Nature and Properties of X-Rays; Influence of Matter on X-Rays; Production of X-Rays; Detecting and Recording X-Rays; An Installation for Industrial Radiography; Making a Radiograph; Photographic Procedure; Interpreting Radiographs; Industrial Fluoroscopy; Radiography of Large Castings and Forgings; Radiography of Welded Vessels and Structures; Radiography of Small Objects; Some Interesting Examples; Operating and Cost Data; Radiography with Gamma-Rays; Tables; Charts; Bibliography. Published by John Wiley & Sons, Inc. Copies may be obtained through AMERICAN WELDING SOCIETY.

"Car and Aircraft Construction," the fourth volume of the series "Selected Welded Constructions," compiled and published by the Committee on Welding in the *Verein deutscher Ingenieure* (VDI) In conformity with the idea underlying the publication of the whole series, the fourth volume offers a collection of photographs and drawings showing typical and well-designed welded joints used in the construction of road and rail vehicles and aircraft. In view of the fact that constructions of high merit, designed in every

respect with regard to the requirements of welding practice, have been evolved in this field, this volume, like its predecessors, will prove a useful aid and guide to the designer of welded constructions. "Shipbuilding," Volume 5 of series "Selected Welded Constructions." Also in shipbuilding, welding is conquering one field of application after another. The foremost requirements of light-weight and tight joints are making shipbuilders realize to an increasing extent the advantages of welded constructions. Systematic tests comparing the strength of welded and riveted joints, carried out on testing machines of up to 1500 tons capacity, have demonstrated the superiority of the welded joint for longitudinal as well as transverse and corner seams. Experience gained from collisions and stranded vessels furnished corroboration. The new vol. 5 of the series of "Selected Welded Constructions" contains an abundance of examples showing welded joints of proved merit and thereby furnishes the designer of ships with information which will enable him to avoid faulty constructions and the troubles arising from them.

(*Continued from page 2*).

Secretary. The Secretary will certify to the competence and signature of all voters returning endorsed nomination ballots and will then deliver them to the Nominating Committee.

A nomination ballot without autographic endorsement of the voter written on the outside envelope is defective and shall not be canvassed by the Nominating Committee. The Nominating Committee shall first open and destroy the outer envelopes of all properly endorsed ballots and shall then open the inner envelopes, canvass the ballots and certify the results to the Secretary. If no nominations, other than proposed by the committee, are made by 25 qualified members, then the Secretary shall treat the nomination ballots as election ballots and certify the results to the Presiding Officer at the first session of the Annual Meeting in April.

(*c*) If a member, not proposed by the Nominating Committee, is duly nominated as provided for in paragraph (*a*) of this Section then the Secretary shall mail, on or before the first Tuesday in March of each year, to each member entitled to vote a ballot stating the names of the candidates for the several offices falling vacant, the time of the closure of the voting. The voter shall prepare his ballot by indicating by means of a cross opposite the name of each candidate he wishes to vote for. The voter shall enclose said ballot in an envelope and seal same. He shall then enclose the sealed envelope in a second envelope marked "Ballot for Officers," seal same and write his name thereon in ink, for identification. The ballot thus prepared and enclosed shall be mailed or delivered unopened to the Tellers of Election.

The Secretary shall certify to the competence and signatures of all voters. A ballot without the autographic endorsement of the voter written on the outside envelope is defective and shall be rejected by the Tellers of Election. A ballot which has choice indicated for more names than there are offices to be filled is defective and shall be rejected by the Tellers.

Article VII. Section 1.—With the approval of the Board of Directors, the President shall appoint the following committees:

(*a*) An Executive Committee, which shall have such duties, as may be prescribed by the Directors to facilitate their work and such power of the Directors as they may delegate to it from time to time.

(*b*) Finance Committee, *consisting of members of the Board of Directors*, which shall pass upon all expenditures, prepare the annual budget, and have general charge of the finances of the Society. The Treasurer shall be Chairman of the Finance Committee.

(*c*) A Membership Committee of five *or more* whose duties shall be to *formulate plans and prepare literature for increasing the membership of the Society*, to pass upon applications for membership in the Society and *handle* such *other matters as may be duly assigned to it.*

(*d*) A Meetings and Papers Committee which shall plan and make arrangements for the meetings of the Society. It shall also solicit and pass upon all papers offered for presentation to the Society, and determine which of the papers presented at the Section meetings shall be published in the Proceedings. It shall also have power to edit papers before publication.

(*e*) A Nominating Committee of five members to be appointed on or before the 15th of December of each year. This Committee shall consist of a Chairman who shall be a past President of the Society and four members, not members of the Board of Directors. The Committee shall deliver to the Secretary in writing, on or before the last Tuesday in January, the names of its nominees for the various elective offices next falling vacant with a written consent of each nominee.

(*f*) A Revision of By-Laws Committee comprising a Chairman (member of Board of Directors) and one representative from each Section selected by the Section Chairman, which shall receive suggestions for revision of the By-Laws and be responsible for the preliminary wording of such revisions. It shall see that the By-Laws of Sections of the Society shall not conflict with any provision of the Constitution and By-Laws of the AMERICAN WELDING SOCIETY. This committee shall be responsible for obtaining the signatures of 10 members to any petition for revision as specified under Article XIII and shall transmit such petition or petitions to the Secretary to be presented at a Board of Director's meeting as specified under Article XIII.

(*g*) A Committee on Code of Principles of Conduct consisting of five members comprising a Chairman (member of Board of Directors) and four additional members. In addition to the function of formulating and administering a code, it shall be the duty of the Committee to advise inquirers regarding questions of proper conduct, and to investigate any practice of any member of this Society which shall be regarded as prejudicial to the welfare of the Society, and report its actions and recommednation to the Board of Directors, which shall take such action as it may deem proper.

(*h*) A committee or committees for a definite stated purpose or purposes may be proposed by any member of the Society in good standing together with the personnel of such a committee or committees but the final selection of the personnel must be by a majority vote (of the quorum) at one of the meetings of the Society as set forth under Article VIII, Section 1, provided the necessary quorum, per Article VIII Sect. 3 is present and further provided that definite notice stating all purposes and objectives of such committee or committees shall have been sent to each member, and/or published in the JOURNAL OF THE AMERICAN WELDING SOCIETY for the preceding month, so as to reach the membership at least two weeks prior to said meeting at which the committee or committees will be proposed and elected.

(*i*) With the approval of the Board of Directors the President may appoint additional committees for a definite stated purpose *or purposes.*

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A group of Russian Engineers, residing in St. Louis, Missouri, have formed an organization known as "The Bureau of Russian Technical Translations."

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